SEWAGE AND INDUSTRIAL WASTES

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

1958 Literature Review, Part III—Research Committee Water Pollution

DO Analyzer—Macklin et al.

Paperboard Wastes Spray Irrigation—Koch and Bloodgood

ABS Removal by Adsorption—Renn and Barada

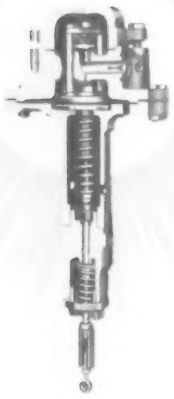
Stabilization Ponds—Howells and Dubois

Operator's Corner

TV in Sewer Inspection, Chemical Coagulation

JULY 1959—VOL. 31, No. 7

POSITIVE CONTROL OF MATERIALS IN MOTION B·I·F METERS FEEDERS CONTROLS



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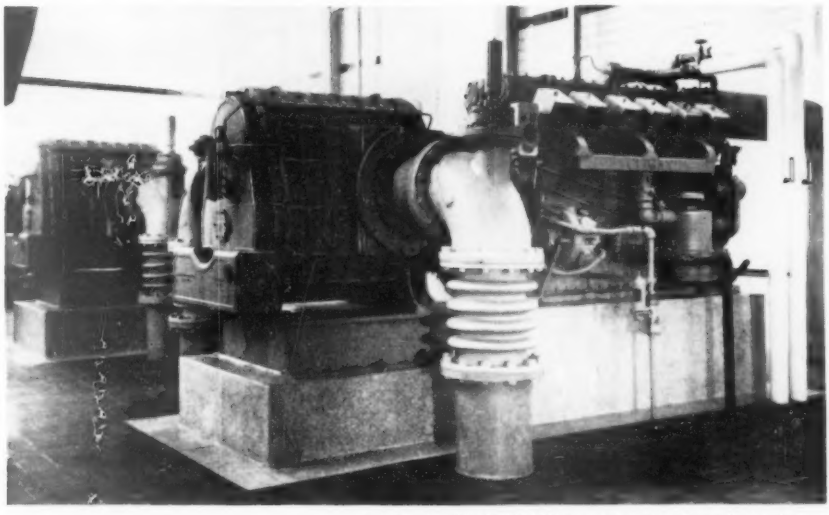

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 31 | **July 1959** | **Number 7**

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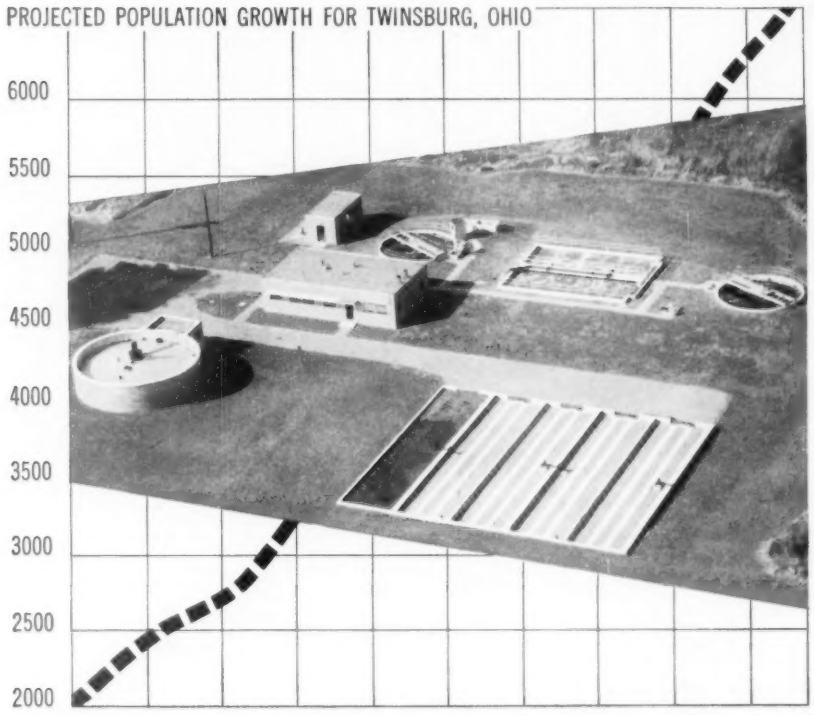

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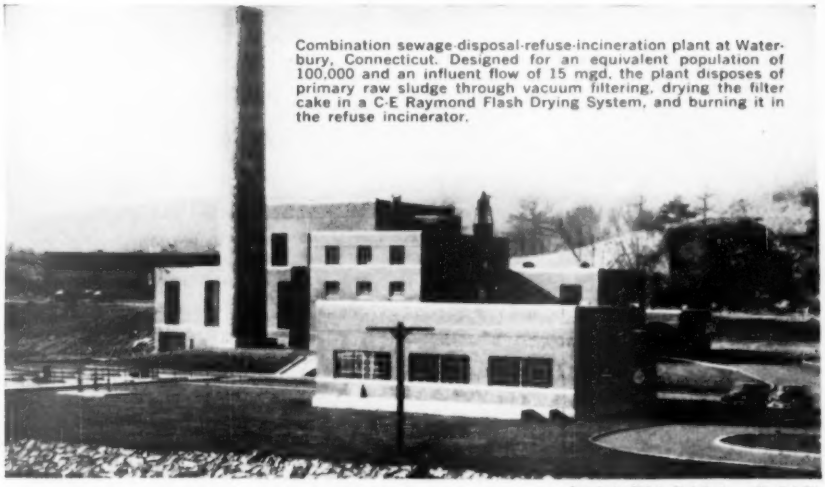

Combination sewage-disposal-refuse-incineration plant at Waterbury, Connecticut. Designed for an equivalent population of 100,000 and an influent flow of 15 mgd, the plant disposes of primary raw sludge through vacuum filtering, drying the filter cake in a C-E Raymond Flash Drying System, and burning it in the refuse incinerator.

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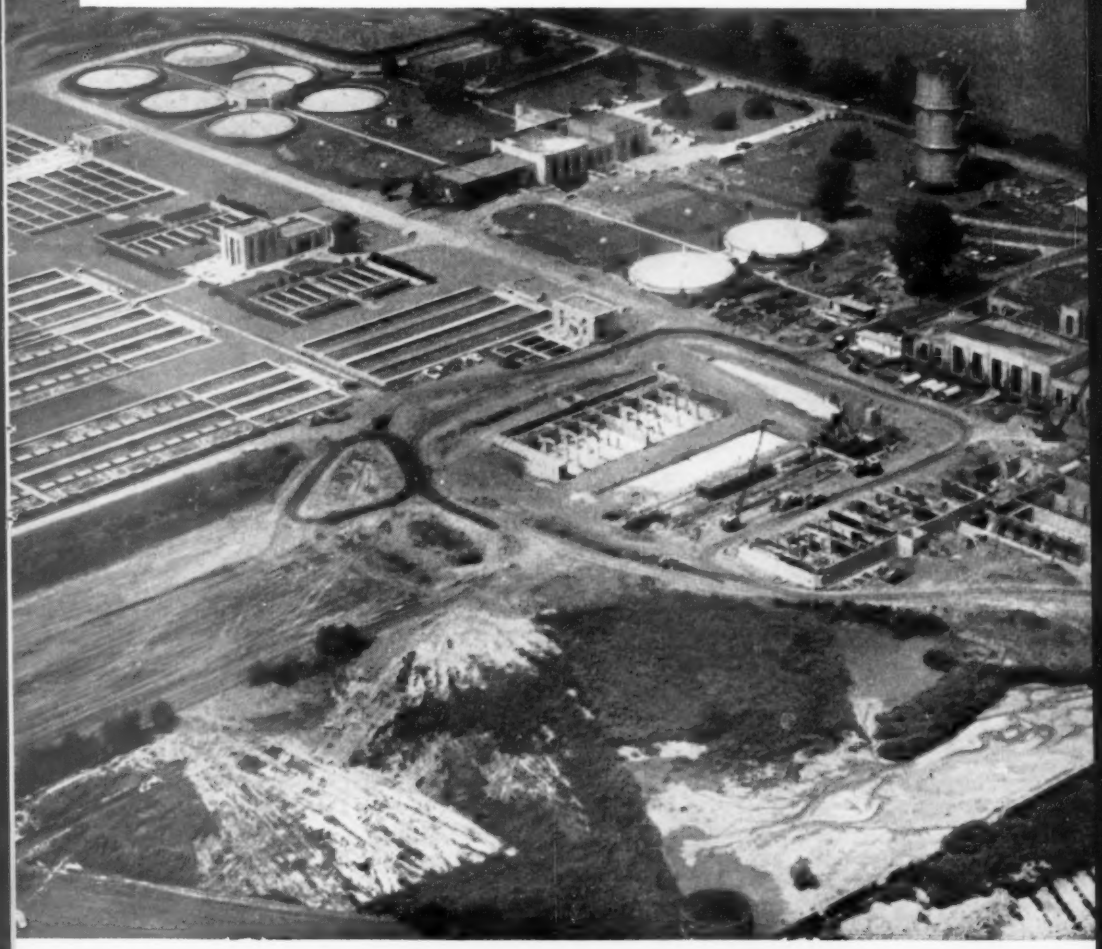

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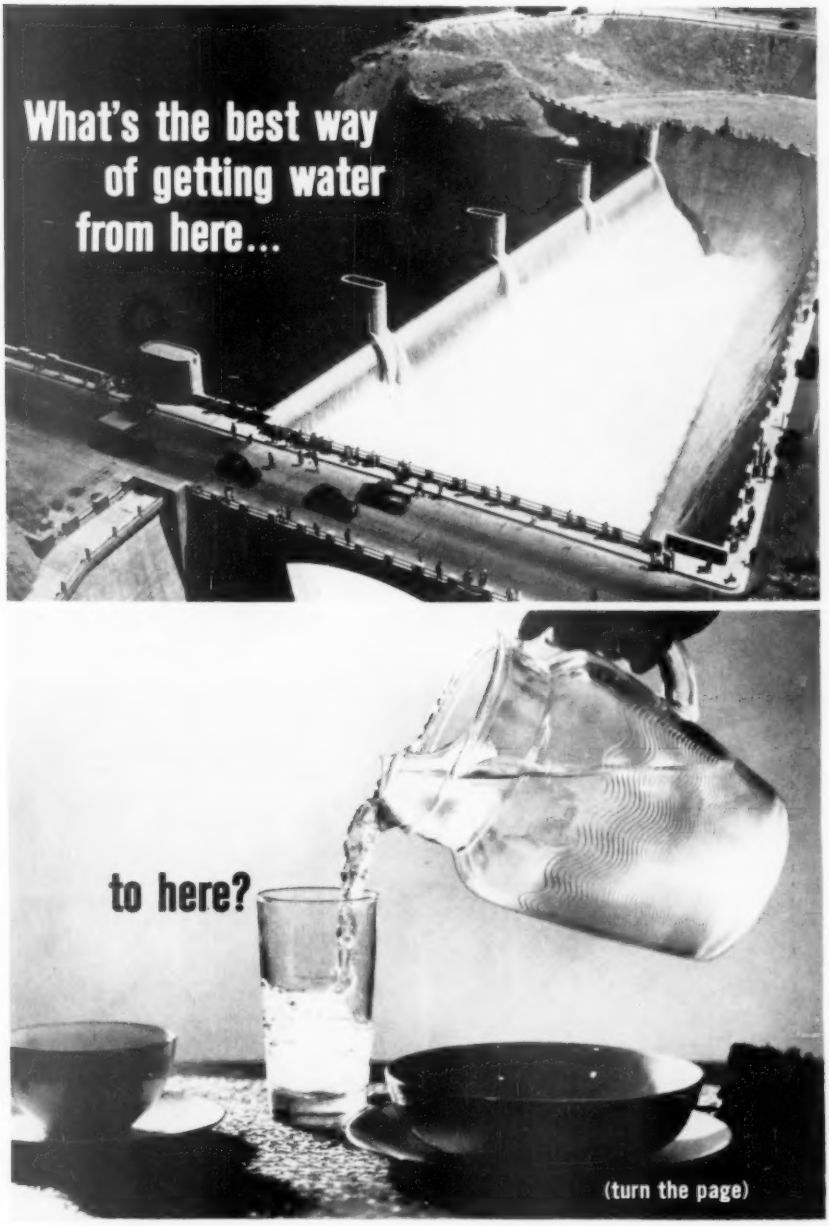
Association	*Place*	*Time*
Puerto Rico Water and Sewage Works Assn.	Intercontinental Hotel San Juan, P. R.	July 10, 1959
Pennsylvania Sewage and Industrial Wastes Assn.	Pennsylvania State University University Park, Pa.	Aug. 12–14, 1959
South Dakota Water and Sewage Works Conf.	Marvin Hughitt Hotel Huron, S. Dak.	Sept. 2–4, 1959
Rocky Mountain Sewage and Industrial Wastes Assn.	Jackson Lodge Jackson, Wyo.	Sept. 8–10, 1959
Georgia Water and Sewage Assn.	Georgia Inst. of Technology Atlanta, Ga.	Sept. 9–11, 1959
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Lafayette Hotel Lexington, Ky.	Sept. 14–16, 1959
North Dakota Water and Sewage Works Conf.	Dacotah Hotel Grand Forks, N. D.	Sept. 23–25, 1959
Missouri Water and Sewerage Conf.	President Hotel Kansas City, Mo.	Sept. 27–29, 1959
Canadian Institute on Sewage and Sanitation	Royal York Hotel Toronto, Ont.	Sept. 28–30, 1959

THIRTY-SECOND ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
Host—Sewage and Industrial Wastes Section,
Texas Water and Sewage Works Association
Statler Hilton Hotel, Dallas, Texas

Technical Meetings and Exhibits—Dallas Memorial Auditorium
October 12–15, 1959

New England Sewage and Industrial Wastes Assn.	Biltmore Hotel Providence, R. I.	Oct. 21–22, 1959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of getting water
from here...
to here?
(turn the page)

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Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, 3440 Prudential Plaza, Chicago 1, Ill.

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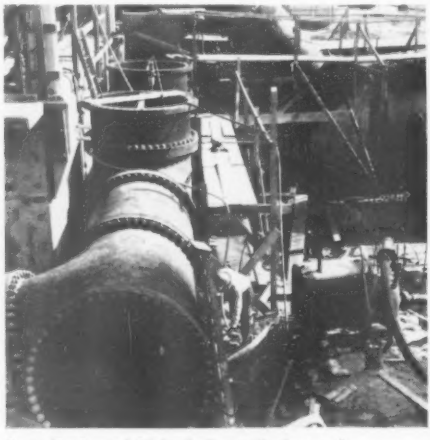

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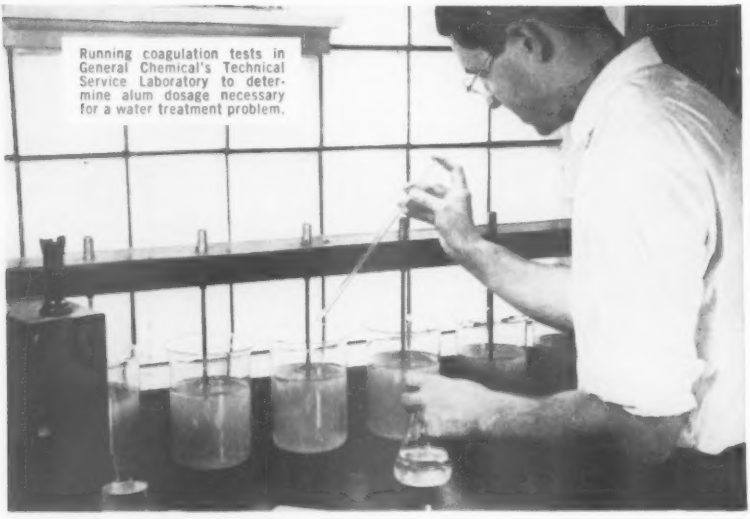
- *Tremendous load resistance.* Six-inch cast iron pipe (Class 150) withstands a load of nearly nine tons per foot!
- *Pressure-tight joints.* You have a complete choice of leakproof, easy-to-assemble joints. You need a minimum of tools and work crew.
- *Ease of tapping.* No tapping saddles needed. Takes threading best of all kinds of pipe.

...good reasons for <u>you</u> to choose

CAST IRON PIPE

THE MARK OF THE 100-YEAR PIPE


Running coagulation tests in General Chemical's Technical Service Laboratory to determine alum dosage necessary for a water treatment problem.

in GENERAL CHEMICAL ALUM

Another difference is TECHNICAL SERVICE

As the country's primary producer of aluminum sulfate, General Chemical constantly helps customers solve technical problems involving the use of alum. Results? Improved efficiency and reduced operating costs for them. Here are some of the services our Technical Service Department offers:

- Supplying basic information helpful in planning design and installation of storing, pumping, metering and feeding facilities.
- Suggesting improvements to eliminate existing storing and handling problems.
- Providing chemists and operators with physical and chemical data necessary for the most effective use of alum.
- Assisting in laboratory tests and plant trials.
- Running check analyses in our own laboratories.

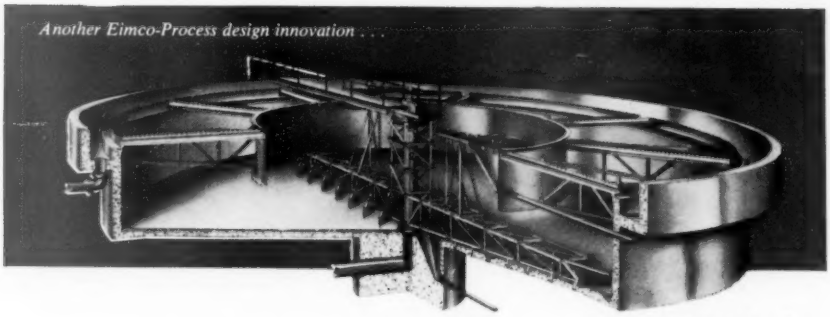
In water and sewage plants, our specialists provide valuable help and guidance on storage, handling and feeding problems, as well as the important conversion from dry to liquid alum. They can help plant operators establish the best alum dosage. They recommend coagulation aids to improve flocculation in difficult water or waste treatment conditions.

This kind of Technical Service is one of the reasons why General Chemical is a good company to do business with for *your* plant's aluminum sulfate requirements. We will welcome the opportunity to serve you.

Basic to America's Progress

Allied Chemical

GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N. Y.



Cutaway drawing of Type C Flotator-Clarifier, a center column supported unit suitable for tanks to 100 ft. diameter. Beam supported mechanisms are available for smaller tanks.

EIMCO-PROCESS FLOTATOR-CLARIFIER PROVIDES EXCELLENT REMOVALS ON WIDELY VARYING FLOWS

Specifically designed to handle waste flow surges yet operate efficiently during periods of low flow, the Flotator-Clarifier represents a new concept in clarification. Through a combination of dissolved air flotation and conventional sedimentation in a single tank, all types of solids—settleable, floating and those which tend to remain in suspension—are rapidly removed. Septicity and odor formation are minimized, and suspended solids, C.O.D. and B.O.D. removals equivalent to those of a conventional clarifier are obtained in about half the tank area.

The Flotator-Clarifier is available in a variety of types, sizes, modifications, and with complete or partial pressurization. It is ideally suited to primary clarification in sewage treatment; oil, grease and other suspended solids removal from trade wastes; and removal or recovery of finely divided solids and low specific gravity liquids from industrial process streams.

This Eimco-Process design innovation has been proved in a number of installations operating with excellent results. If you are concerned with the treatment of sewage or wastes with widely varying flows or composition, it will pay you to consider use of the Flotator-Clarifier. You will find no other equipment possesses its economy, flexibility and wide application.

Bulletin SM-1008 covers design features of the Flotator-Clarifier. Bulletin B-292 describes the Isleton installation, shown below, in more detail. Copies are yours on request.

THE EIMCO CORPORATION
Salt Lake City, Utah

PROCESS ENGINEERS, INC. *division*
420 Peninsular Avenue
San Mateo, Calif.

B - 419

. . . another outstanding installation

Partial feed pressurization and recirculation are features of this 32 ft. dia. Flotator-Clarifier at the Isleton, California, primary sewage treatment plant. The unit provides proper treatment of seasonal peak loads of cannery wastes, yet operates during periods of low flow without creating septic or malodorous conditions. Solano Engineers Associated, Vallejo, Calif., were the consulting engineers responsible for the design of this plant.

Spray application of Rigortex 3310 Enamel, hot-applied vinyl, to concrete pipes. 2630 gallons of Primer and Enamel were used on this job.

Inertol® Hot-Vinyl Coating Protects South River Interceptor Sewer Pipe

As part of New Jersey's Raritan River clean-up project, the Middlesex County Sewerage Authority was to lay 25,370 lineal feet of concrete interceptor sewer pipe. In addition to domestic sewage, the pipe was to carry harsh acid and alkaline industrial wastes.

Too big a job for bituminous coatings, consulting engineers Bogert and Childs specified the Inertol Rigortex® 3310 Hot-Vinyl System. It has outstanding resistance to chemical conditions–including hydrocarbon wastes. It bonds exceptionally well and provides high-velocity flow. It is economical–gives almost 5 times as great mil thickness per coat as cold-applied vinyls, plus 30% savings in labor, and 10% in material.

First, one coat of Rigortex 3310 Primer was applied by spray (dry film thickness of 1.5 mils). Then one coat of Rigortex 3310 Enamel was applied by hot-spray (4.5 mils), producing the specified total dry film thickness of 6.0 mils.

A paint best suited to *your* problem can be selected from Inertol Company's complete line of protective-decorative coatings. Buy Inertol paints direct from manufacturer. Shipment within 3 days from our plant or warehouse stocks in your area. Write for Rigortex 3310 specifications on your letterhead, giving your title. For full specifications on Inertol coatings for sewage plants and water works, ask for free booklet SI-751.

A complete line of quality coatings for water, sewage and industrial wastes plants and swimming pools.

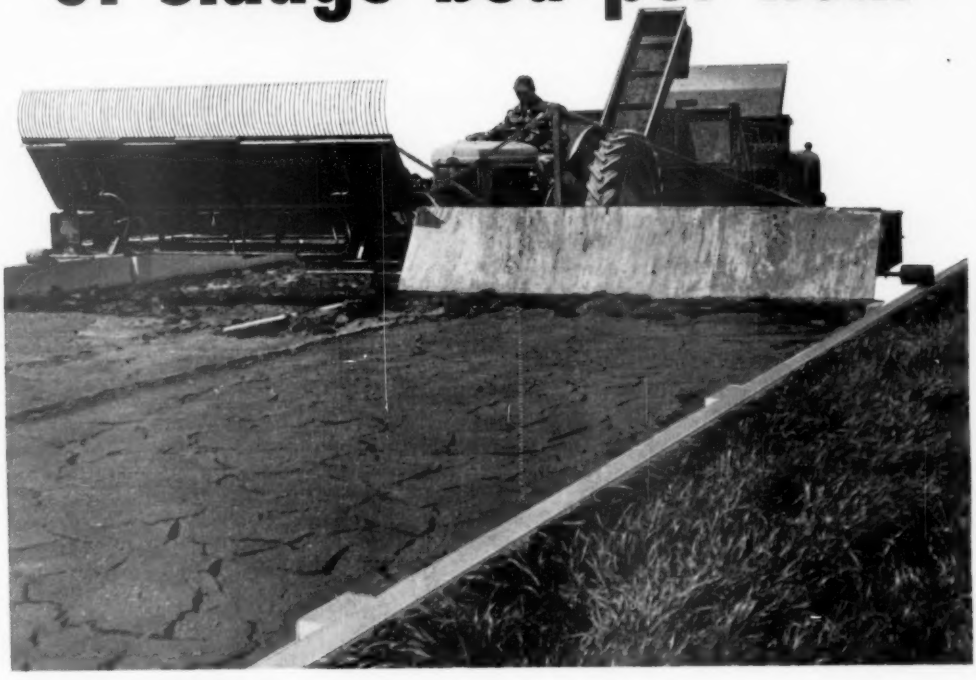
Inertol®

INERTOL CO., INC.

482 Frelinghuysen Ave., Newark 12, N. J. • 27-H South Park, San Francisco 7, Calif.

Visit our Booth at the F.S.I.W.A. Show, Dallas, Texas, Oct. 11–15, 1959

Cleans up to 120 feet of sludge bed per hour



Mechanical cleaner provides faster and more efficient sludge removal than conventional hand cleaning methods

Here's a mechanized method of cleaning sludge beds that will pay for itself in a relatively short time. While individual savings depend on such variables as size of plant, available manpower, method of disposal, etc., annual savings of 60% have been reported over conventional hand cleaning.

The sludge bed cleaner offered by Link-Belt is essentially a conveyor system on wheels . . . the system is mounted on a standard tractor, which travels on concrete runways in sand beds and cleans a path up to 26 feet in width. Performance-proven Link-Belt conveying and power transmission components are combined into an efficient mechanism that is operated by hydraulic motors.

The cleaning cycle works like this. Forked scoops assure minimum loss of filter bed sand. The scoops are raised alternately, elevating the sludge and chuting it over a front truss. Sludge is conveyed by two wing conveyors into a trough where it is pushed along by a center longitudinal flght conveyor. This conveyor carries the sludge up a 45° incline where it is deposited in a truck that is towed or driven behind the tractor.

For more detailed information on how you can clean sludge beds faster, more efficiently, call your nearest Link-Belt office. Send for Folder No. 2671.

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. Sanitary Engineering Regional Offices—Colmar, Pa., Chicago 9, Kansas City 8, Mo., San Francisco 24. Sales Offices in All Principal Cities. Export Office, New York 7. Representatives Throughout the World. 14.902

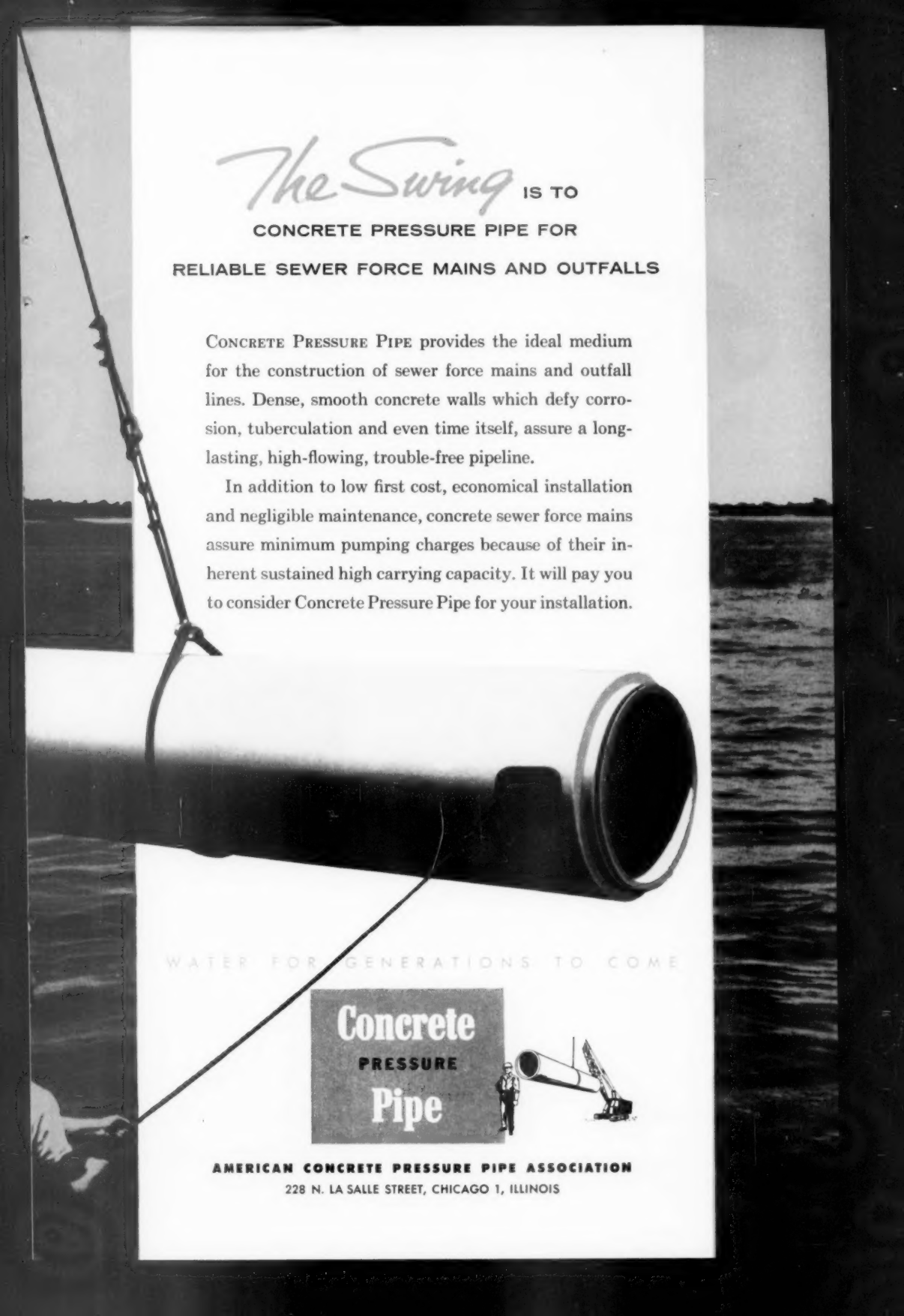
The Swing IS TO

CONCRETE PRESSURE PIPE FOR

RELIABLE SEWER FORCE MAINS AND OUTFALLS

CONCRETE PRESSURE PIPE provides the ideal medium for the construction of sewer force mains and outfall lines. Dense, smooth concrete walls which defy corrosion, tuberculation and even time itself, assure a long-lasting, high-flowing, trouble-free pipeline.

In addition to low first cost, economical installation and negligible maintenance, concrete sewer force mains assure minimum pumping charges because of their inherent sustained high carrying capacity. It will pay you to consider Concrete Pressure Pipe for your installation.

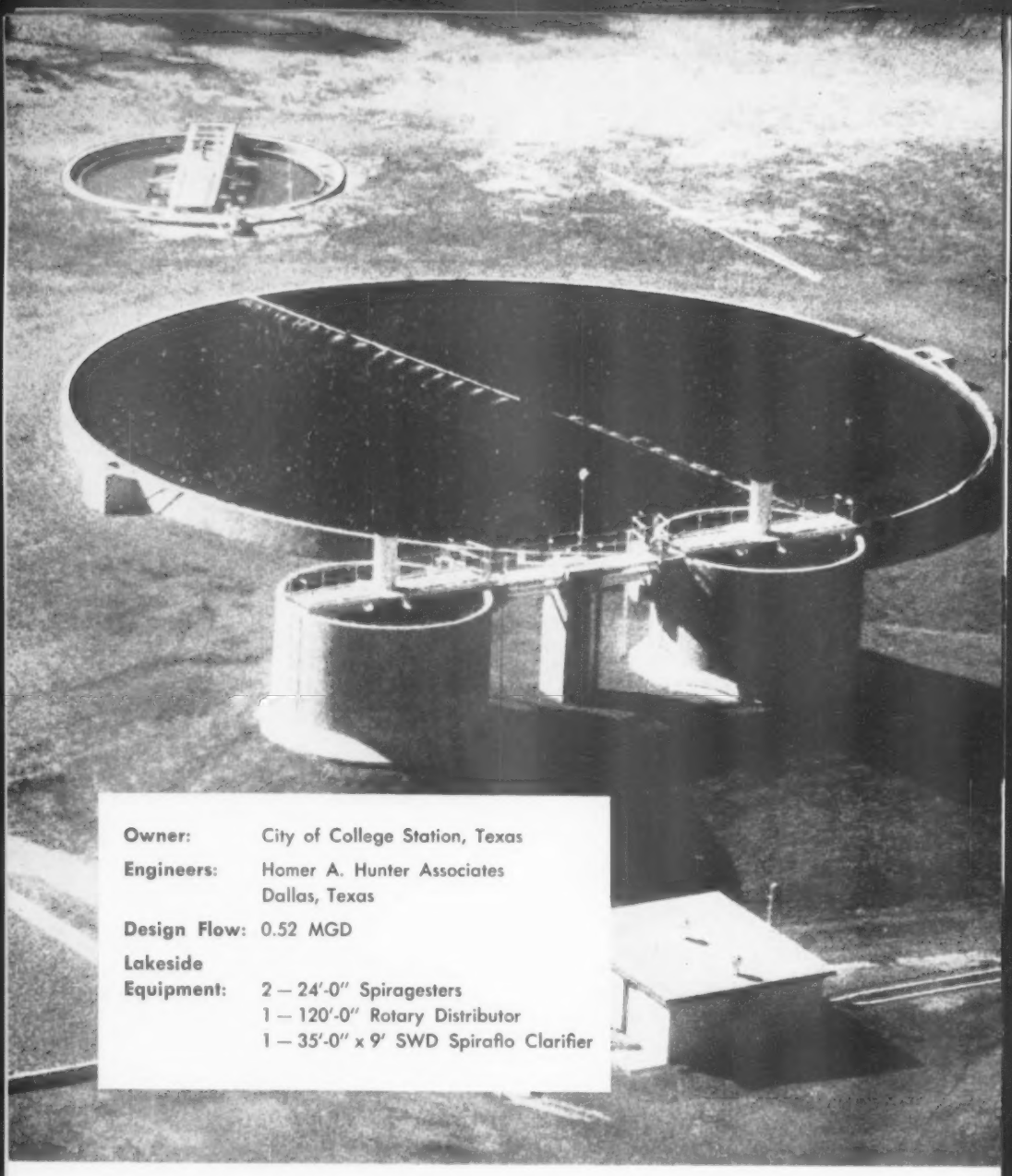


WATER FOR GENERATIONS TO COME

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION

228 N. LA SALLE STREET, CHICAGO 1, ILLINOIS



Owner:	City of College Station, Texas
Engineers:	Homer A. Hunter Associates Dallas, Texas
Design Flow:	0.52 MGD
Lakeside Equipment:	2 — 24′-0″ Spiragesters 1 — 120′-0″ Rotary Distributor 1 — 35′-0″ x 9′ SWD Spiraflo Clarifier

SPIRAGESTERS® are used singly for projects under 6000 P.E. They give superior results with the minimum of operating skill. Construction and operating costs are among the lowest. Plant expansion available by adding another Spiragester or easily converting the tank to a digester. Spiragesters are now installed throughout the U. S. Also Canada and foreign countries. As at College Station, Lakeside provides trickling filter and Spiraflo final clarifier equipment for a complete treatment plant. ***Write for Bulletin 100.***

LAKESIDE

ENGINEERING CORPORATION

222 West Adams St., Chicago 6, Illinois

WHEN CITIES PLAN INDUSTRIAL GROWTH

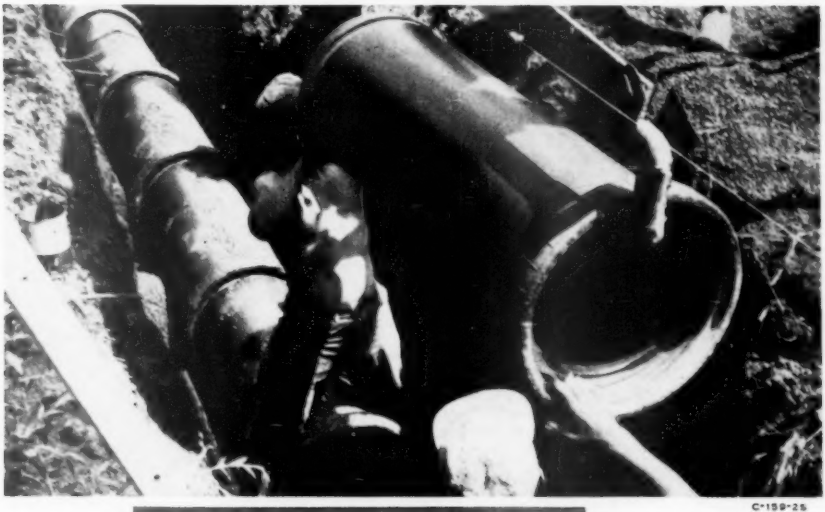
IT PAYS TO SPECIFY CLAY PIPE

SANTA PAULA, CALIFORNIA, already a bustling center of agricultural activity, is building to share in California's phenomenal industrial growth. To accommodate new industry and meet the needs of a growing population, Santa Paula recently completed a bond-financed sewer expansion project, using Vitrified Clay Pipe exclusively. Over 6 miles of Vitrified Clay Pipe were installed.

Like Santa Paula, growing communities everywhere need the permanence and safety that only Clay Pipe can provide. Clay Pipe is the only pipe that never wears out . . . does not rust, rot, corrode, or crumble. And with its new research-developed, factory-made joints, Clay Pipe is faster and easier to install than ever before.

When your community plans new sewerage facilities, be sure to consider the exceptional advantages of Clay Pipe. Its exclusive long-term guarantee is your assurance of permanent, maintenance-free service. Only Clay Pipe has *all* the features you can trust to handle industrial growth.

CITY OFFICIALS: James E. Leary, Mayor; Edwin C. Bixby, Ernest H. Oman, Ralph B. Crawford, Reece B. McCalister, Councilmen.
CONSULTING ENGINEERS: J. M. Montgomery Engineering Co. **CONTRACTOR:** N. P. Van Volkenburgh Co.



C-159-25

Vitrified **CLAY PIPE** *Never Wears Out*

NATIONAL CLAY PIPE MANUFACTURERS, INC.

1820 N St. N. W., Washington 6, D. C.

311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio • 703 Ninth & Hill Bldg., Los Angeles 15, Calif.
Box 172, Barrington, Illinois • 1401 Peachtree St., N. E., Atlanta 9, Georgia

GRAVER SYSTEMS SIMPLIFY TREATMENT OF COMPLICATED PLATING WASTES at MARTIN-ORLANDO

Building missiles is a complex job. Thousands of intricate parts must be machined to close tolerances and plated or coated with a wide variety of materials to resist corrosion and guarantee dependable performance during flight. Many are chrome plated, silver plated, anodized, phosphatized, pickled, passivated or processed in other ways. An unusually large number of acid and chemical wastes results, including nitric acid, hydrofluoric acid, sulfuric acid, caustic and cyanide. Handling these wastes is a complex problem in itself.

Martin-Orlando of Florida, builders of guided missiles, selected Graver to supply all units and auxiliary equipment for a treatment plant based on plans and specifications prepared by the Architect-Engineers. Graver, working with the consulting engineers, fabricated and installed a plant which handles this treatment problem simply and directly. Four integrated systems effectively treat all wastes in the spent baths and rinse. The plant is safe, efficient and simple to operate and maintain.

This installation is only one of the many modern plating waste treatment systems Graver has furnished for large and small manufacturers in every field. Graver supplies all types of equipment, from simple units to entire plants and makes available a complete service, including research and development, manufacturing and installation, when required. Whatever *your* waste treatment requirements, Graver has the modern designs, equipment and processes to do the job efficiently . . . economically. Every installation is tailored to specific needs.

GRAVER

Industrial Waste Treatment Dept. W-520
GRAVER WATER CONDITIONING CO.
Division of Union Tank Car Company
216 West 14th Street, New York 11, N. Y.

WRITE FOR INFORMATION AND LITERATURE!

Architects & Engineers:
Connell, Pierce, Garland & Friedman
Miami, Florida

the problem...

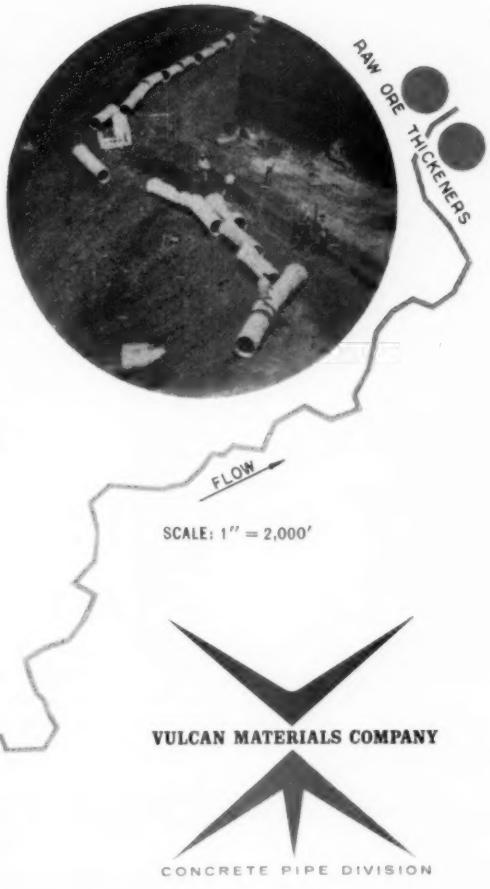
The Problem: To move a mountain of nickel ore down to sea level.

The Project: Mining operation of Freeport Nickel Company (subsidiary of Freeport Sulphur Company) at Moa Bay, Oriente Province, Cuba.

The Engineer: Bedell and Nelson, New Orleans, La.

The Solution: Making a slurry of the ore and moving it by gravity on a 1½ per cent grade through nearly three miles of 24" Cen-Vi-Ro pipe.

The Result: An ore moving system of unparalleled economy.



VULCAN MATERIALS COMPANY

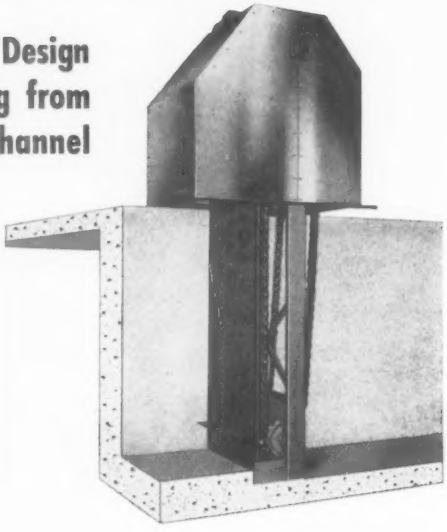
CONCRETE PIPE DIVISION

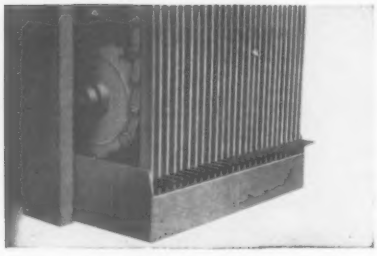
3030 Peachtree Road, Atlanta, Georgia CEdar 3-7127

COMPLETELY AUTOMATIC MECHANICALLY CLEANED

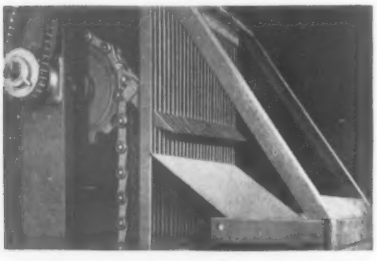
UNIT BAR SCREEN

Exclusive Pivoted Rake Design Assures Positive Raking from Absolute Bottom of Channel





Horizontal position of rake teeth at the beginning of cleaning cycle accomplishes raking from absolute bottom of channel. Gets under and picks up all screenings—does not push them away • Note unobstructed channel approach.



Rake making 45° radial drop to discharge screenings into trough—Note shear pin hub with tool steel shaft and hub inserts for perfect shear action.

THE "AMERICAN" UNIT SCREEN

Completely automatic with a limit switch which stops operation with the rake out of the flow when time control or water level control cycles have been completed • Easily installed as a unit in concrete channels • Total height of unit from mounting floor to motor base is only five feet • The entire above-floor structure is enclosed with stainless steel panels secured by quick opening fasteners to permit easy inspection and access.

Send for TECHNICAL SUPPLEMENT "MS"

AMERICAN WELL WORKS

IN OUR 91ST YEAR
110 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH • ENGINEERING • MANUFACTURING

Offices: Chicago • New York • Cleveland • Cincinnati • Kansas City • Sales Representatives throughout the World

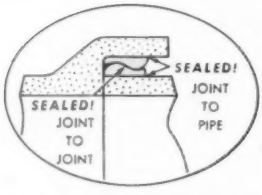
Wedge-Lock®

THE JOINT with the

Full Circle PROTECTION

MINIMUM INFILTRATION! ROOT-TIGHT SEAL!

FAST INSTALLATION!



When you install Vitrified Clay Pipe with Wedge-Lock Factory-Made Joints, you leave nothing to chance. Wedge-Lock pre-cast Joints are bonded to bell and spigot . . . snap together instantly . . . seal the entire circumference of the pipe to reduce infiltration and resist roots. Always specify Wedge-Lock, your Full Circle of Protection against infiltration . . . root problems . . . job delays . . . ultimate high cost resulting from costly repairs or maintenance.

Write to listed manufacturers for literature or an actual Wedge-Lock demonstration

Wedge-Lock CLAY PIPE

THE FACTORY-JOINTED CLAY PIPE AVAILABLE NATIONALLY FROM LOCAL MANUFACTURERS

Order Wedge-Lock from any of these Vitrified Clay Pipe Manufacturers:

Cannelton Sewer Pipe Company Cannelton, Ind.

The Clay City Pipe Company Uhrichsville, Ohio

The Evans Pipe Company Uhrichsville, Ohio

Graff-Kittanning Clay Products Worthington, Pa.

Larson Clay Pipe Company Detroit, Mich.

The Logan Clay Products Company Logan, Ohio

The Robinson Clay Product Company Akron, Ohio

The Stillwater Clay Products Company Cleveland, Ohio

Superior Clay Corporation, Uhrichsville, Ohio

WLC 159-185-B

Water Clean-Up

...it's like finding a new source

Jeffrey traveling water screens and grit collectors in a pulp mill

Jeffrey water cleaning equipment can improve your plant operations and profits. Note these examples.

Jeffrey collectors at a steel mill

Jeffrey screens on water intake at a refinery

Use present source more effectively: In a pulp and paper mill, Jeffrey traveling screens reclaim 16,000 gallons of water per minute by removing tons of sand and bark. Production can be increased without having to seek a new water supply.

Reduce wear on plant machinery: In a steel mill, Jeffrey collectors remove metallic scale from process water, adding considerably to life of bearings. Also, downtime required for cleaning settling tanks was cut from 10 days to a day and a half.

Reclaim valuable materials: In many industries, Jeffrey screens and collectors are salvaging materials formerly carried away in process and wash water. Their recovery produces welcome additions to profits.

Jeffrey engineers will help analyze your waste problems and suggest means of recovery, disposal or neutralization. Bulletin 905 gives further information. For a copy, write Jeffrey Manufacturing Company, 902 North Fourth Street, Columbus 16, Ohio.

JEFFREY

CONVEYING • PROCESSING • MINING EQUIPMENT...TRANSMISSION MACHINERY...CONTRACT MANUFACTURING

Specify
IOWA
for every job
Iowa's complete line of valves for treatment plants assures you of efficient operation, low maintenance cost, and replacement parts when needed in years to come.

IOWA CHECK VALVES—Swing gate type for use in either horizontal or vertical pipe lines. Bronze trimmed throughout. Stainless steel hinge pins. Leather or rubber faced gates, or solid bronze, as desired—aluminum gates available for air service.

IOWA MEDIUM AND LOW PRESSURE VALVES—either non-rising stem or outside screw and yoke types. Designed as carefully as those conforming to A.W.W.A. specifications but with lighter construction for lower pressures.

White TODAY for descriptive literature

IOWA FLAP VALVES—all iron; can be furnished with bronze hinge bolts or fully bronze mounted—including bronze bolts, flap ring and seat ring—when required.

CLOW HYDROSTATIC RELIEF VALVES — commonly used in bottom of concrete tanks to prevent ground water from floating the tank. Close-grained cast iron body and lid; lead seat ring and lid ring. Cast iron grate in bottom prevents foreign matter from entering tank.

IOWA PLUG DRAIN VALVES—either rising or non-rising stem type. High strength cast iron bodies; bronze stem, operating nut, disc ring and seat ring; rustproof steel bolts and nuts. Handwheels, extension stems, plain or indicating floor stands if required.

IOWA SLUICE GATES—can be used in lines having both seating and unseating pressures. High strength cast iron, bronze mounted, with solid bronze adjustable wedges. Can be equipped with cylinder or motor unit for automatic operation.

IOWA SHEAR GATES—either all iron or iron, bronze mounted. Gate-seating wedges bolted on, permitting replacement without replacing frame.

For 50 years a reliable source for precision engineered products

IOWA VALVE COMPANY

A Subsidiary of James B. Clow & Sons

Oskaloosa, Iowa

Nichols Herreshoff

The Versatile Sludge Furnace...

Only the Nichols Furnace provides this multi-purpose operation . . . Grit, Grease, Screenings and Sludge may be disposed of singly or together in ONE burning operation.

Sludge may be burned or dried in one compact unit.

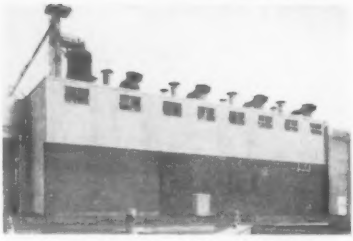
The furnace is a self-contained unit and requires small installation area. Operation is simple, dustless, odorless and presents no hazards. Self-controlled combustion insures freedom from smoke or noxious odors.

Rugged construction assures long life and low maintenance.

Pictured at right are a few of the recent Nichols Herreshoff installations.

Our engineers will be happy to provide more detailed information and assist in the solution of your sewage solids disposal problem—no obligation, of course.

Marietta, Ohio — Consulting Engineers Alden E. Stilson & Assoc.



Indianapolis, Ind. — Consulting Engineers Moore & Heger

Nashville, Tenn. — Consulting Engineers George P. Rice — The Chester Engineers

Mill Creek, Cincinnati, Ohio — Consulting Engineers Havens & Emerson

Nichols Engineering & Research Corp.
70 Pine St., New York 5, N. Y.
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405 Montgomery St., San Francisco 4, Calif.
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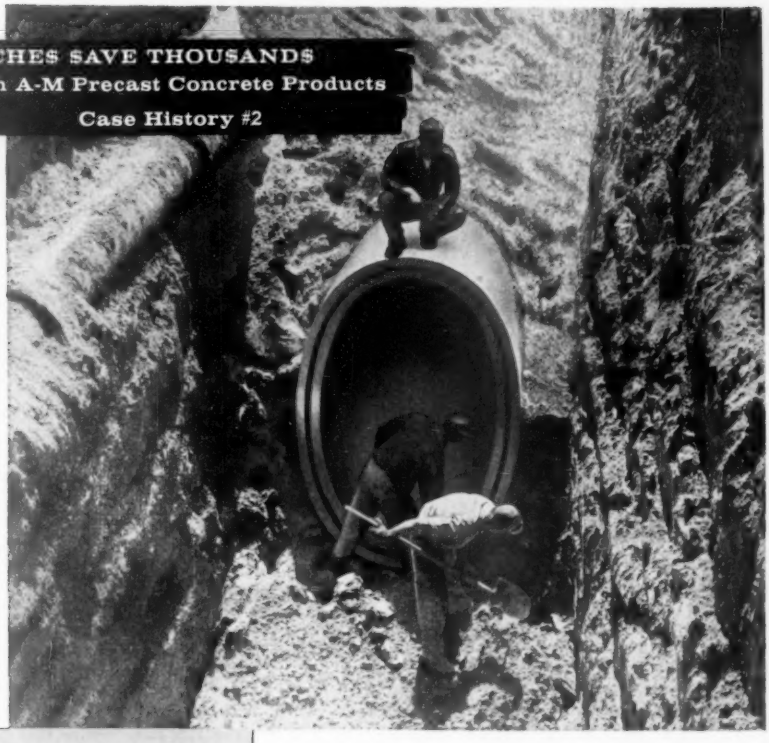
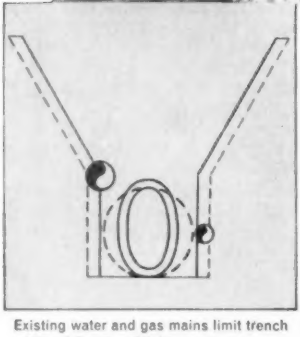
INCHES SAVE THOUSANDS
with A-M Precast Concrete Products
Case History #2



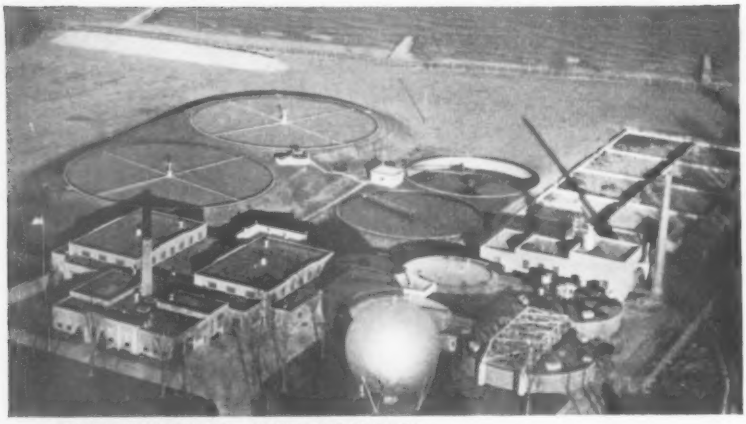


Existing water and gas mains limit trench width of Pontiac, Michigan storm sewer. HI-HED provides greater capacity within a workable area.

A-M HI-HED® PIPE CUTS EXCAVATION COSTS DRASTICALLY!

- 18% narrower than equivalent round pipe, HI-HED Pipe cuts valuable inches from trench widths—can save contractors thousands of dollars in excavation costs.
- HI-HED saves customers the expense of removing or relocating utility lines.
- Another bonus benefit—HI-HED pipe design means higher velocities at low flow.

AMERICAN-MARIETTA COMPANY
CONCRETE PRODUCTS DIVISION
GENERAL OFFICES:
AMERICAN-MARIETTA BUILDING
101 EAST ONTARIO STREET, CHICAGO 11, ILLINOIS, PHONE: WHITEHALL 4-5600



SHEBOYGAN, WISCONSIN

prepares for 1990 with new secondary treatment facilities

An investment of one million dollars has provided the City of Sheboygan with a recently enlarged 8.0 MGD sewage treatment plant. These new secondary treatment facilities are capable of handling the load for a projected population in 1990 of 62,500 at a pro-rata cost to each home owner of less than a dollar per year.

Built in 1937, the original plant used two 80′ diam. Dorr Sifeed Clarifiers and a Dorr Multdigestion System for primary treatment of 6.5 MGD.

A Dorr Single Stage Biofiltration flowsheet providing secondary treatment was used as the basis for the 1958 plant addition. During the initial six months of operation of treating tannery wastes in addition to domestic sewage, an 82% B.O.D. removal was obtained; and this percentage is expected to increase as the filter beds more thoroughly mature.

New equipment in this all D-O equipped plant includes: Two 150′ diam. Dorrco Distributors, two 95′ diam. Dorr final Clarifiers, a 40′ diam. Dorr Densludge Thickener, and a Dorr SSFR Grit Washer. The plant effluent is discharged into the oxygen—rich waters of Lake Michigan. For information on the complete line of Dorr-Oliver equipment for sewage treatment, write Dorr-Oliver Incorporated, Stamford, Connecticut—sales offices in all principal cities throughout the U. S.

Plant Superintendent: Jake Klein
Consulting Engineers: Jerry Donohue Engineering Co.
Bruno J. Hartmen, Pres.
Sheboygan, Wisc.

DORR-OLIVER
INCORPORATED
WORLD - WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD CONNECTICUT U. S. A.

Multdigestion, Sifeed, Densludge, T.M. Reg. U. S. Pat. Off.

1958 Literature Review

A REVIEW OF THE LITERATURE OF 1958 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

By H. Heukelekian, *Chairman*, R. Manganelli, *Vice-Chairman*, H. Amberg, E. J. Berg, H. F. Clark, C. H. Connell, W. E. Dobbins, G. P. Edwards, M. B. Ettinger, D. G. Foulke, T. deS. Furman, I. Gellman, H. G. Harding, R. D. Hoak, R. S. Ingols, W. M. Ingram, P. W. Kabler, M. Katz, F. W. Kittrell, H. G. Luley, P. H. McGauhey, W. A. Moore, R. Porges, E. R. Roth, A. J. Steffen, C. Straub, C. M. Tarzwell, G. H. Teletzke, W. W. Towne, H. A. Trebler, E. C. Tsivoglou, E. Weisberg, and R. L. Woodward

Research Committee, Federation of Sewage and Industrial Wastes Associations

This last of three sections of the Literature Review covers water pollution. The first section, dealing with analytical methods and sewage, was published in the May 1959 issue of This Journal. The second section, on industrial wastes (including radioactivity), appeared in the June 1959 issue of This Journal.

WATER POLLUTION

Biology

Pollution Surveys and Investigations

Studies by Pentelow *et al.* (177) on the effects of the effluent from the Maple Lodge Works, an activated sludge system treating wastes contributed by 200 to 260 thousand people in the Colne River Valley in England, indicated that there was an apparently flourishing population of warm water fishes living in the undiluted sewage effluent. The abundance of fish varied greatly, with populations being highest in summer and lowest in winter. Fish died when the DO content of the effluent was below 30 per cent of saturation. In two and a half years 10 fish kills were reported. No mortality was attributed to concentrations of ammonia, detergents, or metals present in the sewage effluent. In the Vistula River in Poland, pharmaceutical and tannery wastes caused a very marked reduction in the variety of aquatic organisms in the vicinity of the outfall (233).

Qualitative and quantitative analyses of the aquatic biota were made in connection with pollution surveys of the Laramie and Shoshone Rivers and were reported by Ingols (33). The fisheries of 46 miles of the Shoshone have been seriously impaired by a variety of pollutants which are listed under five headings. Fish production in the Laramie is also affected by a number of factors, including irrigation diversions.

An investigation of the effects of wastes discharged into a bay in Japan indicated that phenol was manifest in the upper layers of sea water in an area having a radius of 0.5 km from the outfall. Contamination of the bottom by iron to the extent of 6 per cent covers an area of 0.5 sq km (210). Limbaugh (145) reported that diving with the use of SCUBA* equipment is helpful in evaluating the effects of the discharge of wastes into the sea. Observations can be made on: (a) flow patterns from outfalls, (b) effects on aquatic populations, and (c) other pollution parameters (145).

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Fish Kills

Acid waters from an operating coal mine killed fish in 16.3 miles of Goose Creek, a tributary of the South Fork of the Kentucky River. Twenty days after the kill, fish population studies indicated 61.3 lb of fish per acre above the mine outfall and 5.4 lb per acre below the outfall. The fish killed were valued at $13,325.00. Pan fish comprised the largest group in the kill according to Turner (220). It has been found that wastes from the manufacture of superphosphates and other chemicals which may be nontoxic in sea water at normal pH levels become toxic when the pH is lowered. A large kill of fish in the San Francisco Bay in 1957 is attributed to the action of a combination of factors (6). Grune (104) reported that French authorities determined that a U. S. Army Quartermaster laundry was responsible for several fish kills in the stream receiving the laundry wastes.

Water Quality Criteria for Aquatic Life

General

Sylvester (211) discussed the water quality of the Columbia River wherein it has been significantly changed in the past 45 years due to the construction of dams. The use of water for agricultural, industrial, and domestic purposes has increased. Water returned from these uses differs in quality from the original stream water. Water temperatures in the central Columbia, the lower Snake, and in the Yakima are now quite high in summer and dissolved solids are considerably higher. Wilcox (226) stated that return irrigation water contains more dissolved solids and is generally warmer than the original stream water. Water used for irrigation should not have over 1 to 2 mg/l of boron and the content of sodium, bicarbonate, and other materials which affect plant growth should be low.

Antagonistic relationships between manganese and iron, and between calcium and manganese in relation to algae growth have been demonstrated by Gerloff and Skoog (95). The manganese content of lake waters appears to reach levels high enough to be toxic to algae were it not for this antagonistic action of calcium. The relative requirements and availability of nitrogen and phosphorus for growth of *Microcystis aeruginosa* in southern Wisconsin lakes was also evaluated by the same authors (96). It was demonstrated

* Self-contained underwater breathing apparatus.

that nitrogen content is often close to the limiting amount and that nitrogen is present in far less abundant supply relative to need than is phosphorus. The practical implication of these results is the possible control of blooms by the removal of nitrogen or other limiting nutrients.

Suspended Solids and Turbidity

In studies by Robinson (190), concentrations of certain suspended materials as high as 1,458 mg/l were filtered and passed through the gut of *Daphnia magna* with no apparent harm while others were toxic at much lower levels. Charcoal and montmorillonite were toxic at 100 mg/l; ground glass at 98 mg/l; chlorite at 120 mg/l; and illite at 264 mg/l. Pond sediments were not toxic at any of the tested levels.

Temperature

Studies of the effect of temperature on reproduction by Hubbs and Strawn (120) have indicated that temperature and condition are the controlling factors. At extreme temperatures fish are not ripe at seasons when nearby populations under favorable temperatures are in spawning condition. Light duration and intensity do not appear to affect fecundity of greenthroated darters. For this species optimum temperature for egg production appears to be between 20° and 23°C.

Temperatures in the main stem of the Columbia River during the period of egg development of the chinook salmon are usually about 57°F at spawning time, then they drop to 36°F, and later increase to about 47°F. Experimental studies by Olsen and Foster (169) with groups of chinook eggs at temperatures averaging 4°F colder and 2°, 4°, and 8°F warmer, indicated that significant mortality above that in the controls occurred only in the warmest lot. The results of these studies indicate that incubation can begin at temperatures as high as 61°F without significant loss.

Rainbow trout held in distribution tanks at 54°F died when planted in a southeastern Wisconsin lake having a surface water temperature of 74°F. Since this latter temperature is not lethal in nature, it is thought by Threinen (217) that it was the change in temperature which was lethal to the planted fish. Fish slowly acclimated to the higher temperature survived.

Two groups of goldfish with a mean weight of 14.2 g were subjected to two different photo periods by Hoar (115). The first group received 8 hr of illumination and 16 hr of darkness while the second group received 16 hr of illumination and 8 hr of darkness. Both groups were held at the same temperature and received the same intensity of light. The first situation corresponded to sunlight in winter and the second to summer sunlight. When the thermal resistance of the two groups was tested it was found that the first group survived low temperatures best; whereas the second group was the most resistant to high temperatures.

The temperature of the cooling water of the Johnsonville, Tennessee, steam plant is raised about 10°F in winter and 5° to 6°F in April and May. While no significant increase in plankton production was noted due to the warming of the harbor receiving this effluent, some differences in fish population were noted by Dryer and Benson (72). Threadfin shad were attracted in large numbers and they, in turn, attracted the sauger which feeds on them.

Dissolved Solids

Investigations by Parry (175) on the osmo-regulation of 3 species of salmonids (*Salmo salar, Salmo trutta,* and *Salmo gairdneri*) demonstrated that the tolerance of these fishes to sea water and their ability to regulate body fluids in water of high salinities depends on the size of the fish as well as on its age and species. The maximum

tolerances of selected organisms for sodium chloride in mg/l at 20° and 3°C, respectively, were determined by laboratory studies to be as follows: *Stictochironomus*, 788 and 1,000; an oligochaete, 1,576 and 2,000; *Daphnia magna*, 200 and 800; *Cyclops serrulatus*, 394; *Leucaspisis delineatus*, 1,970; and nitrifying bacteria, first and second stages, respectively, 1,970 and 20,000 (127). Gordon (101) reported that adult arctic char (*Salvelinus alpinus*) taken in summer from Hebron Fjord, Labrador, and Hudson Bay near Churchill, Manitoba, were transferred directly from salt to fresh water under fairly constant conditions. Decreases in blood freezing point and chloride concentration of about 25 per cent were found, indicating that the char is like most other anadromous salmonids in this respect.

Twenty-four-hr median tolerance limits of bluegills to oil field brines were found by Wood (231) to range from 8,100 mg/l to 10,500 mg/l total chlorides, depending on the source of the brine. Tolerance decreased as the period of exposure increased. It was found that $CaCl_2$ was more toxic than NaCl and that when they were mixed in equal quantities, the combination was less toxic than either individually. It was deemed possible to construct physiologically balanced brines which would not be lethal to certain fresh water fish at 10,000 mg/l. Tests with mayfly nymphs indicated that their 24-hr TL_m was about 10,000 mg/l and their 72-hr tolerance about 3,600 mg/l chlorides. Thus, concentrations which are safe for certain fish are lethal for certain mayflies. Tests with two refinery wastes indicated that they were toxic to fishes.

Studies by Clemens and Finnell (59) in an Oklahoma stream receiving oil well brines indicated the average number of kinds of organisms found in areas, with various concentrations of chlorides, to be as follows: 20,000 to 16,000 mg/l, 4.0; 16,000 to 11,000 mg/l, 4.8; 11,000 to 8,000 mg/l, 6.5; 8,000 to 4,000 mg/l, 8.5; 4,000 to 1,000 mg/l, 9.3; and 1,000 to 100 mg/l, 13.0.

Dissolved Oxygen

When eggs of the chum salmon (*Oncorhyncus keta*), which were being hatched at 10°C, were exposed to low DO levels (0.3 ppm) for a period of 7 days and then cultured under normal conditions until hatching was complete, it was found by Alderdice *et al.* (4) that some monstrosities resulted. At 10°C oxygen levels below air-saturation produced delays in the mean hatching rate. Low DO stimulates eggs in an advanced stage of development to hatch prematurely. Critical levels of dissolved oxygen were found to range from about 1 mg/l in early stages to over 7 mg/l shortly before hatching. The same authors (3) reported that for chum salmon eggs, oxygen uptake is independent of the CO_2 level if it does not exceed 125 mg/l. However, at this level there may be a high mortality rate.

Sugiura (208) states that diurnal variations in DO concentrations are almost directly proportional to the phytoplankton population and to the amount of light during the day. A study by Newell (160) of a dam near Jinja, Uganda, has shown that in addition to diurnal fluctuations of DO as a result of photosynthesis and respiration, nocturnal cooling of the surface water can cause overturn and the depletion of surface water oxygen.

During the fall months large amounts of leaves find their way into streams, lakes, and reservoirs. It has been found by Chase and Ferullo (48) that maple leaves under aerobic conditions exert an oxygen demand equivalent to 75 per cent of their weight, while oak leaves and pine needles exert an oxygen demand equivalent to 50 per cent of their weight.

Blazka (28) reported that at 5°C crucian carp (*Carassius carassius*) tolerated for 2 months low DO levels

which they could withstand for only a few hours at 16°C. It is stated that H_2S does not complicate the influence of low DO. The critical tension at 5°C, that is, the lowest DO concentration which does not lower the oxygen consumption, was found to be 1.7 ml of O_2 per liter. In the transportation of fish it was found by Sahan *et al.* (192) that certain absorbents (pulverized earth, activated charcoal, and Amberlite) were effective for the absorption of NH_3 and CO_2, and the increase of the survival period. Carp spawn was found to stand a concentration of 20 mg/l of dissolved CO_2, 2.5 mg/l free NH_3, and 15 mg/l of NH_4^+ in the form of inorganic salts. Studies have been made in India by the same authors (193) to determine the effects of oxygen pressure, free surface area, and water volume on the number of carp fry that may be transported in a closed system.

Dissolved oxygen criteria must insure that DO concentrations are favorable at all times and to all desirable species and their different life history stages. These criteria must be based on a knowledge of the environmental requirements of the organisms which are to be protected from pollution. It is suggested by Tarzwell (214) that these criteria should be expressed in mg/l and should specify favorable levels and the lowest allowable level for short-time exposures. It is believed they should not be expressed as average concentrations or per cent of saturation. While much yet remains to be learned, it is believed that tentative criteria should be set up based on best knowledge and experience. They can be changed in the future when so indicated by new data. For a well-rounded warm water fish population it is recommended that in any 24-hr period the DO shall not be less than 5 mg/l for more than 8 hr and at no time shall it be less than 3 mg/l. For coarse species this lower value may be 2 mg/l. For good salmonid production it is suggested that DO concentrations should not be less than 6 mg/l.

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Toxic Materials and Wastes

Methods

In streams receiving putrescible wastes there is often a diurnal variation in DO values in certain portions of the stream. For some time it has been known that the DO concentration influences the toxicity of some materials to aquatic life. Experiments were conducted by Cairns and Scheier (41) to determine the effect on the toxicity of certain chemicals by periodic lowering of dissolved oxygen to represent conditions in streams with periodic oxygen sag. From a level of 5 to 9 mg/l, DO was lowered slowly by the introduction of nitrogen to a level of 2 mg/l. This level was held for 2 hr and then increased to the normal 5 to 9 mg/l DO. An 8-hr period was allowed for lowering, maintaining, and raising oxygen levels. In the absence of toxic materials these variations in DO levels had no adverse effects on the animals used; however, they did influence the toxic effects of certain materials as indicated by the 96-hr TL_m. Under normal oxygen (5 to 9 mg/l) and low oxygen (2 mg/l), the 96-hr TL_m values, expressed as mg/l, were for selected materials, respectively, as follows for fish: $ZnCl_2$ as Zn^{++}, 8.02 and 4.9; naph-

thenic acid, 5.6 and 2.0; KCN, 0.45 and 0.12; and potassium dichromate, 320 and 320. For snails, corresponding differences in 96-hr TL_m values were as follows: naphthenic acid, 6.6 and 2.0; and KCN, 1.08 and 0.48. These results indicate that periodic low DO levels may result in lower tolerance of organisms to some but not all chemicals.

The marine algae are of genuine importance to the Japanese and concern is felt regarding the impact of various wastes on these organisms. The uptake of phosphorus by these organisms measured by tagging with P^{32} was used as a measure of the well being of these organisms and harmful effects of certain waste material. Wastes tested were sulfite and soda pulp mill effluent. rayon industry wastes, starch mill wastes, H_2S, NaOH, Na_2S, $CuSO_4$, and bleaching powder. All except starch mill wastes were found to be harmful (85). The effects of certain industrial wastes and chemicals on a bivalve were also studied from the physiological standpoint. The opening and closing of the shells of the bivalve were used as a measure of the toxicity of substances. Calcium uptake was also used as a criterion. The velocity of uptake was determined through the use of Ca^{45}, which was dissolved in sea water containing various concentrations of wastes. The bivalves were cultured in these mixtures and their uptake of Ca determined by radiological means (83).

The toxicity of pulp mill wastes is a particularly difficult problem since many constituents of the waste are not known and there may be antagonisms, synergisms, and other reactions. Thus, Warren and Doudoroff (222) state that bio-assays offer the most reliable method of determining their toxicity potential to fishes. At Niagara Falls, N. Y., Reid (187) tells of the program of E. I. du Pont de Nemours & Co., wherein bio-assays were instituted using fish indigenous to the area to determine the toxicity of their wastes. Carp, perch, and silver bass were used in determining 24- and 48-hr TL_m values for the wastes. Based on the waste evaluation program, process improvements were made to recover valuable materials and combinations of wastes from several processes were used to treat toxic wastes to an acceptable level.

It has been pointed out by Beak (23) that TL_m values denote acute toxicity and they alone do not provide a ready means for determining the concentration of a waste which is suitable under conditions of continuous exposure. However, the use and value of bio-assays in detecting and evaluating toxic waste problems, in selecting waste treatment methods, in continuously monitoring wastes, and as a tool in the enforcement of pollution regulations, are pointed out by Tarzwell (213).

In the future the increasing demands for water will result in more widespread multiple use. This will require the treatment of wastes to protect and preserve receiving waters for selected beneficial uses. The outstanding present problem in the disposal of metal plating wastes is their toxicity to aquatic life. It is believed by Tarzwell (212) that bio-assay is the most effective and efficient tool for determining the toxicity of such wastes, the effectiveness of treatment processes, and the amounts which can be safely discharged to the particular stream receiving the wastes.

Metals

The 48-hr TL_m of hexavalent chromium by 10- to 11-in. *Micropterus salmoides* was found by Fromm and Schiffman (82) to be 195 mg/l. After 2.5 hr exposure to 94 mg/l Cr, there was a slight increase in the oxygen consumption of the fish followed by a gradual decline to 27 per cent below normal, after 68 hr exposure. After 84 hr exposure all test fish were dead, there was a widespread destruction of the intestinal epithelium, and the intestinal folds were greatly reduced in size.

Fisher (78), in tests to determine the toxic effects of $CuSO_4$ on *Daphnia, Cyclops,* and chironomids, found that the former was most sensitive, followed by the chironomids, and then *Cyclops.* The $CuSO_4$ was more toxic at higher temperatures while equal concentrations differed in toxicity in different waters, being most toxic in distilled water, tap water, and pond water, in the order named. Lowering the pH also increased toxicity. In experiments with pyridylmercuric acetate (PMA) by Clemens and Sneed (61) it was also found that this material was more toxic at higher temperatures. The 8-hr TL_m was 21.1 mg/l at 10°C; 10.8 mg/l at 16.5°C; and 5.8 mg/l at 24°C. There was also some difference in toxicity for fish of different ages. The 24-hr TL_m was about 5 mg/l for yolk fry; 2.18 mg/l for 1-week-old fry; and 3.75 mg/l for 2-month-old fingerlings. Experiments were carried out with Hg^{203} by Corner and Rigler (63), labelled *n*-amylmercuric chloride and mercuric chloride, to study the modes of action of these compounds in some crustaceans. Differences between the susceptibilities of *Artemia salina* and *Elminius modestus* to the poisons do not reflect differences between quantities of these compounds which the animals can tolerate in their tissues but are directly related to the rates at which the poisons are accumulated. The Hg penetrates into the tissues and does not act simply by becoming attached to the surface.

Jones (125) reports that the River Ystwyth continues to be polluted by effluents from derelict lead and zinc mines 35 yr after the end of mining operations. Lead has become negligible but zinc is present in the main stream in concentrations of 0.2 to 0.7 mg/l, according to river level. The flora above the mine is rich but below it is poor in quantity and variety. Bottom samples below the mine indicated animal populations of 161 to 373 organisms per 2,500 sq cm of bottom. Brown trout now occur in the river.

Bio-assays to determine the median tolerance limit of *Notropsis hudsonius* to sodium arsenite indicated the following TL_m values: 24-hr, 45 mg/l; 48-hr, 29 mg/l; and 72-hr, 27 mg/l. Even lower concentrations had a corrosive action on fin and tail tissue after 96 hr. No mortality occurred in concentrations of 15 mg/l As, which is the highest concentration used for control of water weeds (32).

In their annual report for 1957, the British Water Pollution Research Board describes their work on the toxicity to fish of metallic salts, which is being carried out at the Water Pollution Research Laboratory (17). It was found that Zn salts are more toxic to fingerling rainbow trout in soft water than in hard water and that the addition of $CaCl_2$ reduces the toxicity of Zn. There were indications that Zn in suspension exerts as much toxic effect as if it were in solution. Experiments using $ZnSO_4$, labelled with radioactive Zn, have shown that Zn does enter the bodies of fish and can possibly act as an internal poison.

Phenolic Compounds

Investigations of phenols in gas liquors have shown that they are more toxic to fishes than are the equivalent solution of pure phenol. The toxicity of phenols is increased by a reduction in the DO concentration. Biological treatment of gas liquors removed the phenols but not the NH_3 and the waste liquor was still toxic (17).

A screening program was set up for the purpose of finding materials having a selective toxicity for lamprey larvae such that they could be used to kill lampreys without killing fishes. Applegate *et al.* (19) reported that six mononitrophenols containing halogens were found which were significantly more toxic to lamprey larvae than to other aquatic organisms. Under conditions which simulated actual stream conditions the toxic effects of each of the sub-

stances on fish seemed to be much less than those obtained in the jar tests, but for the lamprey larvae they were essentially the same. In the stream tests the selective toxicity for lampreys of 3-trifluormethyl 4-nitrophenol was accentuated.

In acute and chronic phenol poisoning of fish there is no bleeding from the gills. The fish die of symptoms which are usual in nerve poisoning. Suffocation occurs with the same symptoms as for a lack of oxygen; that is, too much blood in the gills, and blood coagulation in the heart cavity (110). Sodium pentachlorophenate has been shown by Berka (26) to be extremely toxic to fishes. Concentrations as low as 0.04 mg/l have been lethal to minnows. Its toxicity is influenced by temperature and pH.

Pulp and Paper Mill Wastes

Japanese workers (84) have used paper electrophoresis in the evaluation of the physiological effects of paper mill wastes on fishes. Electrophoresis of the serum of fish subjected to various portions or concentrations of the waste have shown that concentrations of acid or alkali which have affected the paper electrophoretic patterns and damaged gill tissues were almost equal. Further, the pattern for suffocated fish differed from normal fish and fish affected by pulp mill wastes could be distinguished from controls experimentally. By this method the physiological effective concentration of pulp mill waste for fish was estimated to be as low as 30 to 50 mg/l COD value.

Studies have been made by Berthier *et al.* (27) to determine the constituents of black liquor and their toxicity to fish and bacteria. It was reported that the lignin derivatives were more toxic than the hemicelluloses. More detailed studies were made to determine the toxicity of the turpentine fraction of the black liquor. It was found that the toxicity of pure oil of turpentine was similar to that of the crude liquor but the fraction of the liquor distilled off at 150° to 160°C which should be comparable in composition to the oil of turpentine was much more toxic. This is attributed to the presence of traces of highly toxic organic sulfur compounds. Neale (159) states that the disposal of wastes from pulp and paper mills is of special interest when receiving waters are important for shellfishes and sport and commercial fishing. Chemical pulping wastes involve problems of low DO, toxicity, and nuisance growths. In the lower Columbia River and in the Spokane River *Sphaerotilus* problems have developed and fish kills have occurred in some harbors and river estuaries. The depressing influences of pulping wastes on water quality were also reflected by a rapid decline in several oyster producing areas in lower Puget Sound and an inhibiting influence on commercial and recreational fishing activities in much of the lower Columbia River. Research at Bowman's Bay has indicated that the threshold mortality indexes for the downstream migration of chinook and pink salmon occurs at concentrations of sulfite waste liquor between 500 and 600 mg/l for exposure periods of 30 days or more.

Insecticides

Prior to 1944 insecticides were, with a few minor exceptions, inorganic materials. Since the appearance of DDT there has been a constant search for more toxic organic insecticides. While DDT is still the most widely used material many newer materials are being widely used and each year sees an increase in the amount of organic pesticides used. Since these materials are toxic to a great variety of animals and they are now being broadcast over extensive areas they are becoming important as water pollutants. This increase in importance is reflected by a corresponding increase in the literature on their toxic or pollutional effects.

According to Corbet (62), the use of

DDT in the upper Nile did not appreciably affect some of the aquatic macroinvertebrates but others, especially the *Ephemeroptera* and *Trichoptera,* were virtually eliminated. As these organisms are important as fish food their destruction was serious from the standpoint of fish production.

The toxicity of DDT to brook trout fry, salmon fry, and 1- and 2-yr-old parrs was studied in hatchery troughs by Gagnon (89) using large numbers of fishes. DDT applied at the equivalent of 0.5 lb/acre (0.32 mg/l) resulted in a 93 to 100 per cent kill of salmon and trout fry and 1-yr-old parrs. In other series of experiments it was shown that sensitivity of salmon decreased with age and that the TL_m was 0.072 mg/l. Time for this kill was not stated.

Field investigations were conducted by Davis *et al.* (68) to evaluate DDT, dieldrin, and parathion for the control of blackfly larvae in slow-moving Florida and South Carolina streams. Parathion at 0.5 and 1.0 mg/l eliminated all larvae in 1.6 miles of stream after 5 min but did not exercise control 2.3 miles downstream even with applications up to 24 min. In South Carolina 10- and 20-min applications gave control over 2.8 miles of stream, which is about 10 times that secured with DDT.

In the northwest Miramichi watershed which was sprayed in 1954 and again in 1956, there was a serious reduction in the stream bottom fauna. Annual seining showed that large parr were very scarce in 1956. Small parr resulting from the 1955 hatch were more abundant, averaging 37 per 100 sq yd. They were thin and in poor condition. Fry of the year were very scarce in the sprayed areas but were present in about half normal abundance in the areas not sprayed since 1954. In the area sprayed in 1956, they averaged 2 per 100 sq yd. The 1954 spraying had serious effects on the stream insects and these effects were still evident in 1956. Caddis flies were eliminated in 1954 and had not reappeared in 1956. Young salmon are directly affected by DDT spraying and they are also adversely affected by a reduction in the bottom macroinvertebrates (5). Burden (37) reported that the use of DDT for the control of the green chironomid *Tanytarsus lewsii* resulted in large fish kills. The DDT was applied at a rate to give a concentration of 0.09 mg/l and 10 miles downstream the concentration was 0.017 mg/l. Fish died 8 miles downstream. The disposal of chlorinated hydrocarbon wastes at sea resulted in toxicity to plankton organisms (118).

In studies by Stringer and McMynn (206) eight alkaline lakes in British Columbia were treated with toxaphene at concentrations of 0.10 to 0.01 mg/l. At all concentrations most of the fish which were killed died within 120 hr. All fish were killed and the lakes were still toxic to fish 8 or 9 months later. Amphipods were eliminated at all concentrations and were still absent 9 months after poisoning. Dragonflies, damselflies, and midge larvae were killed at a concentration of 0.03 mg/l. In Michigan lakes which were treated with 0.010 to 0.025 mg/l of emulsifiable toxaphene the small fish died before the large ones (86). No mortality was observed in a lake treated at the rate of 0.002 mg/l but the small fishes were killed in one treated at the rate of 0.005 mg/l. These findings suggest that a concentration of 0.005 mg/l toxaphene can be used to reduce the population of small fish in hard water lakes without seriously affecting the large fish.

The airplane application of dieldrin pellets at the rate of 1 lb of the technical material per acre resulted in a substantially complete fish kill in 2,000 acres of Florida east-coast tidal marsh. It was estimated by Harrington and Bidlingmayer (108) that 20 to 30 tons of fishes were killed. Mollusks seemed to be unharmed by the treatment but crustaceans were virtually exterminated. The entire aquatic crab and fiddler crab populations were annihi-

lated. Repopulation by fishes began slowly about 4 weeks after the kill.

Laboratory tests were made by Chin and Allen (50) with BHC to determine its toxicity to shrimp. For *P. setiferus* the 24-hr TL_m was 35 ppb and it was 400 ppb for *P. aztecus*. Webbe (224) indicated that larvicidal concentrattions of DDT were very toxic to *Tilapia melanopleura, T. macrochir,* and *T. pangani*. Two per cent dieldrin granules at dosages of 5 to 10 lb/acre were toxic to all three species. A 3 per cent BHC powder applied at the rate of 1 lb/week/acre for 16 weeks did not kill the fish.

Bio-assay to determine the toxicity of endrin to fishes (122) showed that it was less toxic at lower temperatures. The 48-hr TL_m values for carp fingerlings were 0.14 mg/l at 8°C, 0.006 mg/l at 18°C, and 0.005 mg/l at 28°C. Similar experiments showed carp eggs and fry to be far more resistant to endrin than fingerlings. The 24-hr TL_m values were: for eggs, 20 mg/l, for 4-day fry, 4.2 mg/l, for 5-day fry, 0.061 mg/l, and for 2- to 2½-in. fingerlings, 0.005 mg/l. When endrin was applied to rice paddy fields at 1 or 2 lb/acre, toxicity to fish remained for more than a month.

Japanese workers determined the toxicity of 11 pesticides to 4 species of fish and estimated TL_m values for 3, 6, 12, 24, 48, 96, and 240 hr. Of this group of 11 insecticides including DDVP, diazinon, dipterex, ethyl parathion, gusathion, metasystox, DDT, γ-BHC, aldrin, dieldrin, and heptachlor, it was found that aldrin, dieldrin, and gusathion were most toxic (132). Some of the same workers (148) studied the toxicity of 14 argicultural control chemicals to *Daphnia* by means of bio-assay. The amounts in micrograms of each material calculated to be safe for *Daphnia* were as follows: DDVP, 0.2, diazinon, < 0.8, dipterex, < 0.25, ethyl parathion, 0.5, gusathion, 4.3, malathion, 0.2, EPN, < 0.1, DDT, < 2.2, γ-BHC, < 100, aldrin, < 4, dieldrin, < 250, endrin, 50, heptachlor, 20, and derris, 0.1.

Organic Phosphorus Insecticides

Goldfish and the Japanese killifish were kept about a month in sub-lethal levels of parathion and its effects on the fish were observed by Matsue *et al.* (149). At concentrations one-thirtieth the 48-hr TL_m the movements of the gills and pectoral fins were retarded and feeding and growth were decreased. The results show that the permissible concentration of parathion is far lower than one-tenth the 48-hr TL_m. Bio-assays were made with 10 organic phosphorus compounds by Henderson and Pickering (113) to determine their relative toxicity to fish. It was found that the toxicity of these materials varied over a wide range, the 96-hr TL_m ranging from 0.20 to 121 mg/l. No relationship was apparent between toxicity and chemical structure. With one exception water quality had little apparent effect on toxicity. Bluegills were more sensitive to several of these compounds than were fathead minnows. The organic phosphorus compounds were in general less toxic to fish than the chlorinated hydrocarbon insecticides.

A new insecticide called sevin (1-napthyl-N-methylcarbamate) has been found to be fairly nontoxic to some fishes. Ethanol solutions of sevin were used by Haynes *et al.* (111) in bio-assays with goldfish. It was found to have a TL_m of 28 mg/l. The wettable powder had a TL_m of 14 mg/l.

Toxic Materials Produced by Algae

A unialgal culture of *Microcystis aeruginosa* which is toxic when injected intraperitoneally into white mice has been isolated and reported by Hughes *et al.* (121). There seem to be two toxic fractions, a slow and fast death factor. The latter is an endotoxin which is detected only where cells become leaky or disintegrate. The concentration of the fast death factor in

the cells varies with the developmental stage of a culture. Methods have been developed by Abbott and Ballantine (1) for extraction of the toxin from cultures of *Gymnodinium veneficum*. The toxin is soluble in water and the lower alcohols but insoluble in ether and chloroform. The toxin as it occurs in sea water is not the same as paralytic shellfish poison. It is believed to attack the nervous system. *Gymnodinium brevis* has been shown by Ray and Wilson (186) to be toxic to 6 species of fish. It is concluded that this dinoflagellate is the direct cause of the mass mortalities of fish and other marine animals in the Gulf of Mexico. Toxicity of the organism does not depend on the presence of living organisms. "Red tides" which have caused fish mortalities are world-wide in distribution. In a discussion by Ballantine and Abbott (20), it is said that the blue-green alga, *Trichodesmium*, is the causative organism along the east coast of South America, and a few other records refer to organisms belonging to the *Chloromonadineae* and *Chrysophyceae* which cause trouble off the coasts of India and Eurasia.

Other Materials

Studies have been made on the toxicity of Cl_2 to fish. Results indicate that residual Cl_2 at 0.1 mg/l is markedly toxic to trout particularly if the DO is low. At all concentrations of DO used, a given concentration of Cl_2 was more toxic at pH 6.3 than at either pH 7.4 or 8.2 (17). According to Merkens (152) the toxicity of Cl_2 wastes in rivers does not depend directly on the amount of Cl_2 added but upon the concentration of residual Cl remaining in solution.

Rainbow trout were continuously exposed to levels of 0.035 and 0.070 mg/l of separan for a 4-month period with no mortality. Olsen and Foster (168) indicated that slight growth retardation occurred at the concentration of 0.070 mg/l. Lawrence (143) reported

TABLE I.—Toxicity of Several Compounds to Fingerling Channel Catfish

Materials	Temp. (° F)	TL_m Values (mg/l)		
		24-hr	48-hr	96-hr
Pyridylmercuric acetate ("PMA" 80 per cent active)	75	3.8	—	0.49
Trypaflavine	68	11.5	6.8	4.9
Acetic acid	77	446.0	388.0	270.0
Malachite green (oxalate salt)	77	0.14	0.14	0.14
Formalin	77	87.0	69.0	69.0
Phenylmercuric acetate (10 per cent solution)	68	1.46	0.78	0.58

that the herbicide delrad at concentrations of 0.25 and 0.3 mg/l killed large amounts of *Pithophora* in ponds but the effects were of short duration (1 to 3 wk). As many as 3 applications of delrad at 0.3 mg/l in bass brood ponds did not affect spawning of bass, hatching of eggs, or survival of fry and fingerlings. Four applications did not appear to affect bluegills. Minimum lethal concentration for bluegills and largemouth bass is about 0.65 mg/l.

Sodium cyanide has been used as a fish poison in fish management work. Bridges (35) reported that at 1 mg/l it kills fishes at a variety of temperature and pH conditions.

In connection with studies of chemicals for the control of diseases and parasites of channel catfish, bio-assays were conducted by Clemens and Sneed (60) to determine the toxicity of several compounds to fingerling channel catfish. The TL_m values found for the different materials are shown in Table I.

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Organic Wastes

Effects of Organic Enrichment

It has been well established that raw sewage or the effluents from sewage treatment plants contribute fertilizer in the form of nitrates and phosphates and other growth promoting substances to a receiving water. The sum total of these additions frequently results in a highly productive or eutrophic receiving water. Ill effects from sewage, mainly due to algal growths, including toxicity, tastes and odors, and increased BOD, may out-weigh benefits such as oxygenation, mineralization, and production of a food chain. Lackey (141) wrote that perhaps what is needed is treatment so complete as to remove all the nitrogen and phosphorus. Ohle (164) observed that some lakes in the Swiss area have been converted from oligotrophic to eutrophic conditions by the influence of civilization, mainly by increased discharges of organic matter and phosphates. Limnological and biological changes in Lake Zurich since 1896 when the first mass invasion of *Tabellaria fenestrata* and the first deposit of septic sludge were observed are described by Kuhn (139). The lake is now mero-mictic and meso-eutrophic but good water supplies are still being secured. Construction of additional sewage treatment plants is needed and the increase in industry may cause further deterioration.

A year-round study was made on the Mad River by Gaufin (93), a stream receiving heavy organic enrichment and also paper mill waste discharges. Major effects were a decrease in dissolved oxygen of from 2 to 9 mg/l and a corresponding increase in free CO_2 from 0 to 10.5 mg/l. In addition, paper mill wastes blanketed the bottom with paper fibers, making it totally unsuitable as a habitat for most species of macroinvertebrates. A striking difference in the qualitative and quantitative makeup of populations of aquatic macroinvertebrates was observed above and below major waste effluents. The largest number of species, 58, was taken in the headwater section. Of this number nearly half were mayflies, stoneflies, caddis flies, and certain beetles. Only 14 species were collected at any one time in a heavily polluted area. Studies of a river in Wisconsin by Wisniewski (229) showed a marked change in the type of algae from source to mouth. Blue-green algae predominated near the source (a lake) and green algae characteristic of moving waters near the mouth. The production of oxygen from live algae exceeded the oxygen usage in BOD reactions of both live and dead cells, resulting in a significant net gain in dissolved oxygen.

According to Provost (183), in recent years Florida has had an increasing problem with "blind mosquitoes" or chironomid midges which are a nuisance when overly abundant. It appears that overproduction of midges is a product of excessively enriched waters and may be the result of sewage effluents which are rich in nitrogen and phosphorus. Controls with DDT or BHC were ineffective as the midges developed a resistance. Investigations are underway in 19 lakes to determine causes and methods for control. Masses of chironomid tubes were observed by Edwards (73) floating in a channel carrying the effluent from an activated sludge plant. The tubes were composed of sludge that had settled in the bed of the channel. It is suggested that the release of large amounts of organic matter from the benthos in this manner is likely to lower the concentration of dissolved oxygen in the water and thus may produce conditions adverse to fish.

A startling effect of biological imbalance in streams which has become a serious problem below many industrial outfalls is the development of massive growths of filamentous slime-encased bacteria. The effect of a pulp and paper mill in the production of *Sphaerotilus* in the receiving stream and the factors which may be involved were studied by Cawley (44). Biological imbalance caused by substantial amounts of wastes in streams offering high dilutions in the presence of sufficient dissolved oxygen, short chain organic compounds, near neutral pH, and other known and unknown conditions may cause infestations. Similar studies on the composition and causes of slime formation in paper mills were made in Czechoslovakia (147), and various species of bacteria, fungi, and protozoa were identified. The effectiveness of various slime control agents was tested and effective treatment methods determined. In a river in Sweden, a mass development of *Achlya prolifera* was found by Pooth (180) below a factory manufacturing wood fiber sheet. This fungus appeared in parts of the river in which there was an appreciable flow and good aeration. Farther downstream where the river was partly dry, this fungus was replaced by *Leptomitus lacteus*. Proteins were almost completely absent in the river water and the main source of nutrient matter appeared to be the dissolved simple sugars.

The self-purification capacity of a stream is its ability to utilize continually and to render innocuous by physical, chemical, and biological processes dissolved and suspended materials which are added to it. Biological surveys and investigations can be valuable

tools for the determination of the effectiveness of natural purification and the discovery of factors which cause undesirable conditions or limit the purification processes (215). Elevation of pH was suggested by Kreft *et al.* (137) as a possible method for removal of ammonia from sewage effluents.

Indicators of Pollution

The biological examination of polluted waters to determine the extent of pollution and hence the effect on fish received some attention. Various organisms including fungi, bacteria, algae, protozoans, and bottom animals were used as indicators. Studies were made on milk processing plants which encourage extensive growths of *Leptomitus lacteus* and sugar refineries and distilleries which cause growths of *Sphaerotilus natans*. Detailed examination by Wurtz (232) of the form in which the organism occurs indicates the extent of pollution. The biological proofs of pollution should assume the same value given to chemical analyses.

The algal vegetation of the Saline River, Michigan, was studied by Blum (29) over a period of 18 months along with the physico-chemical variables which might influence algal growth. The upper river is unpolluted but the lower course is polluted with industrial wastewaters and sewage which produce a change to a pollution resistant flora. Some organisms were found to be markedly resistant to chromium and other polluting ions. Grenager (103) reports that sewage from one-half million people is discharged at the head of Oslofjord, Norway, which causes very heavy pollution. Most littoral algae show an inner limit which must be considered an effect of pollution. Twenty-four species of algae were studied closely and tolerant and intolerant forms listed. Since 1897 several species of algae have disappeared from the fjord, probably due to pollution.

In a study of a small artificial pond by Bamforth (21), the nature and amount of organic nutrients in the water appeared to influence the numbers of euglenoids and ciliates. The amount of phosphorus seemed to influence which phytoplankters appeared. Chrysomonads were not found when the water contained more than 0.02 mg/l phosphate but cryptomonads and diatoms increased at this concentration. As found by Oldaker (167) slight environmental changes can promote rapid change, reduction, or subsidence of a population. Activated sludges produced in laboratory-scale plants treating trade wastewaters were examined for the presence of stalked protozoa. The author considers that these organisms can be useful indicators of the condition of activated sludge.

In a study of the Mad River in Ohio by Gaufin (93), a total of 166 species representing 122 genera of macroinvertebrates were collected and identified. The largest number of species was taken in the clean headwaters. Very few species were found in heavily polluted sections but some of them occurred in large numbers. By considering the species composition, abundance, and adaptations of the macroinvertebrates collected in the various pollutional zones which were indicated by physico-chemical tests, it was possible to classify such organisms into three categories based upon their reactions to organic enrichment; namely, clean water, facultative, and pollution preferring categories. Bottom fauna in polluted New Zealand streams were studied by Hirsch (114) to devise biological criteria for evaluating the extent and severity of organic pollution. In grossly polluted areas, the fauna is comprised largely of tubificid worms and sometimes includes naiad worms and certain chironomid larvae. In less polluted streams, a molluscan fauna is commonly present. With decreasing degrees of pollution caddis fly larvae and many other organisms

are found to reappear, with the sensitive mayfly group appearing last.

Based on a study of several lakes, Zullig (235) states that the causes of eutrophic conditions in lakes cannot be judged by examination of present chemical and biological conditions only but that examination of the history of the development is necessary. This can be done by examination of cores of bottom sediments taken by borings. Methods developed for such investigations are described.

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Radioactive Wastes

A review of the present situation with respect to the disposal of radioactive wastes was made and the problems that confront fisheries scientists were pointed out by Finn (77). At present only Canada, Russia, the United Kingdom, and the United States are disposing of any substantial quantity of radioactive wastes but other nations will soon be doing the same. There will undoubtedly be a large increase in radioactive wastes and it is believed that the oceans are the obvious place to dump this material. The disposal of these wastes is today a subject of great importance to oceanographers, biologists, and other scientists of the world. The propensity of fish and living organisms to concentrate radioactive elements is one of the dangers inherent in the disposal of radioactive wastes at sea. The problem is very complex and an enormous amount of research and investigation will be necessary to insure that, as the volume of radioactive material grows, it can be disposed of safely. Davis and Foster (69) reported that some radioactive materials introduced into aquatic environments may be accumulated by the organisms. The amount of accumulation will vary over many orders of magnitude, depending on the kinds of isotopes involved and many physical, chemical, and biological factors. The process of adsorption and absorption are of major importance in the uptake of radioisotopes by plants but appear to be of less importance than the food chain in the uptake by aquatic animals. The concentration of radioactive substances will vary between species and tissues and will fluctuate according to food habits, life cycles, and seasonal changes. Where the turnover rates of certain isotopes can be measured, in-

ferences can be drawn on feeding habits of organisms.

In the treatment and disposal of radioactive wastes from the Chalk River, Ontario, plant of Atomic Energy of Canada, Ltd., it is considered that radioactive wastewaters can be safely and effectively disposed of by utilizing the principles of segregation and reduction of wastes at their source, by taking advantage of the natural properties of the materials, and by following an intensive and continuous sampling program (170). At this plant, the limited discharge of fission products to the Ottawa River has resulted in concentrations of radioactivity far below the permissible levels allowed in water. No accumulation of radioactivity in the river organisms has occurred during the years in which the plant has been in operation. During summer, some radiophosphorus is taken up by organisms, but by autumn the radioactivity disappears, owing to the lowered metabolism of the organisms and the short half life of radiophosphorus. A survey of the radioactivity in the waters of the North Equatorial Current from the Marshall Islands to the Marianas Islands was made in September 1956 by Seymour *et al.* (198). The general pattern of distribution of radioactivity shows a sharp decrease east of Bikini and a gradual but irregular decrease west of Eniwetok. A slight degree of contamination was indicated as far west as Guam. Nonfission products account for a large proportion of the radioactivity in plankton and fish samples.

As reported by Tsivoglou *et al.* (219), the uranium ore refining industry is an important source of radioactive liquid wastes. There are 14 operating mills with capacities ranging from 300 to 3,300 tons of ore per day with present total capacity about 15,000 tons per day. During 1955 and 1956, surveys were carried out to determine the effects of wastes discharge on streams. Mills may vary greatly in the discharge of radioactive materials and some radium concentrations were found in excess of usually accepted maximum permissible amounts. Samples of algae, bottom animals, and fish were found to concentrate radium to a marked degree. Radium content of algae samples taken below one mill was 1,500 times that found in samples above the mill. Wastes from uranium mill operations have definite public health significance primarily because of the very long half-lived materials involved.

Numerous laboratory studies were made to determine the uptake of various radionuclides by different organisms. A study by Gong *et al.* (100) of the uptake of 3 neutron-induced radionuclides (Zn^{65}, Fe^{59}, and Co^{60}) and a 2-month-old mixture of fission products by the clam demonstrated the ability of this marine animal to concentrate rapidly significant quantities of these radionuclides in both shell and soft tissue. The uptake of radioactive material in the soft tissue is a metabolic incorporation, while the higher uptake by the shell appears to be a surface adsorption phenomenon. The ability of the clam to concentrate radioelements to a high degree makes it valuable as a biological indicator of radioactivity. Zinc concentrations in sea water and in shellfish samples, collected from inshore waters along the Atlantic and Gulf of Mexico coasts are reported by Chipman *et al.* (51). Oysters, clams, and scallops concentrate large amounts of this trace metal, the oysters containing the greatest amounts. Radioactive Zn added to water was rapidly taken up in large amounts by shellfish. *Nitzschia closterium* apparently concentrates large amounts of Zn^{65}, thus allowing its transfer to marine animals. Marine fish quickly take zinc into the body from the digestive tract but much of it is excreted rather promptly. A small percentage was retained for many days. In studies by Boroughs *et al.* (31) to determine whether marine fish require calcium in their diet, or whether they can take up an adequate amount

from sea water, non-feeding fish (*Tilapia mossambica*) were placed in artificial sea water containing Ca^{45}. The fish took up about 60 per cent of the Ca^{45} in the water. It is concluded that marine fish can take up Ca from the water and do not need a dietary source of this element. From a similar experiment in Russia (133) with strontium, it was concluded that marine fish discriminate against strontium in favor of calcium, either by excreting it faster or by absorbing less. *Daphnia* and *Cyclops* placed in water containing $CaCl_2$ labelled with Ca^{45} were found to concentrate the calcium, so that after 47 hr they contained about 138 mg per 100 g of fresh weight. When transferred to nonradioactive solutions, the concentration of radioactive calcium in their bodies was halved in 30 min. Guppies fed on *Cyclops* which had concentrated Ca^{45} took up the element but the process was slow. Direct uptake from water by the guppies was more rapid. Unialgal cultures of *Euglena* and *Chlorella* grown in three concentrations of Cs^{137} (1, 5, 10 $\mu c/l$) by Williams and Swanson (227) demonstrated that the uptake was linear. Structural components persist in dead *Chlorella* which absorb cesium from very dilute solutions and the absorption is not affected by the concentration of potassium in the medium.

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Microbiology

In 1957, Dauer (67) reported four disease outbreaks for which water was the vehicle of infection. In one outbreak, two persons with typhoid fever had used water from a dug well presumably contaminated by a chronic carrier. Gastroenteritis of unknown etiology occurred in two groups using water from wells that showed evidence of fecal contamination. One small group of enteritis cases appeared among passengers on a plane, where the drinking water was the probable source.

Eighteen cases of infectious hepatitis (not included in previous report) in Davies County, Kentucky, were investigated by Mosley and Smither (158), and the epidemiological evidence indicated that at least 9 of the cases were due to ingestion of water from private wells contaminated from the first known case. It is believed that water-borne hepatitis may be more frequent than is reported, particularly in rural areas where water supplies are often poorly protected.

An epidemic of enteritis was caused by a cross-connection of a city water supply and a sewage polluted bayou through an underground lawn sprinkling system (155). No specific etiological agent was isolated from the patients; however, when the cross-connection to the city supply was removed, the outbreak promptly subsided.

Typhoid bacilli have been demonstrated by Gol'dfarb and Ostrovskaia (99) in river and well water in concentrations as low as 10 to 100 organisms per ml by use of the "increase in phage titre reaction." The sensitivity of this increase in phage titre reaction is said to be appreciably greater than that of bacteriological examination, and depends on the character of the typhoid strain and the presence of other microorganisms in the water. Weber (225) in Germany was able to demonstrate *Salmonellae* in surface waters most efficiently by use of solid media and membrane filter technique. *S. paratyphi B* persisted as long as 3 months and was more resistant than *S.*

typhosa. Viability of the organisms depended both on the conditions of the water and on temperature. Papp (174) determined the *Salmonellae* content of water and sludge samples from the river Oker and its tributaries. The highest *Salmonella* loadings were found below sewage works outfalls. Infection of the stream persisted 15 to 21 miles below the point of sewage discharge. If self-purification had proceeded to the meso-saprobic stage, *Salmonellae* were absent or only sporadically present. Neither natural nor artificial biological treatment removed the *Salmonellae.* Reut (189) showed that the presence of humus in water increased the survival time of *S. typhosa, S. dysenteriae flexneri,* and *E. coli;* while Shrewsbury and Barson (199) found that temperature and pH of the water were important factors affecting the viability of *S. typhosa, S. dysenteriae* varieties *shiga, flexneri, boydii, sonnei;* and *V. cholera.* Luria and Burrous (146) reported that a number of *Shigella* strains were capable of mating with *E. coli.* Matings resulted in formation of hybrids, which exhibited new combinations of characters typical of *Shigella* with characters typical of *E. coli.* The results suggest a possible role of hybridization occurring in nature in the evolution of the *Enterobacteriaceae* and in the origin of aberrant and intermediate strains of enteric bacteria. Ettinger (74) pointed out that the recurrent pattern of oxidative food usage by microorganisms and oxidative destruction of cell substance are essentially similar in natural stream purification and in activated sludge or trickling filter systems.

In July 1955, 73 cases of leptospirosis, type canicola, occurred among the inhabitants of Rostov-on-Don region (234). The spread of the *leptospirae* was by way of a faulty water tower, contaminated by underground water as the result of heavy rains. Five strains of *Leptospira pomona* were isolated from stagnant and rapidly flowing waters in four areas by Gillespie *et al.* (97). The source of infection was probably the urine of cattle suffering from leptospirosis.

Examination of school children in Swaziland by Pitchford (179) revealed high rates of infection with *Schistosoma mansoni* and *S. haematobium.* The spread of infection was fostered by the use of rivers and canals for bathing and washing purposes. Preventive measures such as provisions for more suitable bathing, washing and latrine facilities, control of wastewaters, and the use of molluscicides were recommended.

A collecting bottle for the sampling of water for microbial examination was described by Potter, Osterhoudt, and Baker (182). The collector was designed to insure uncontaminated samples at various depths and to withstand pressures of more than 100 psi. The use of a chelating agent, ethylenediaminetetra-acetate (EDTA), for preservation of coliform organisms in water samples was investigated by Dardanoni and Cordone (66). Eighty-six per cent of the chelated samples gave coliform counts equal to or higher than the untreated samples, and 58 per cent gave significantly higher counts. Hoather (116) found that the bactericidal action of copper can be prevented by the thiosulfate used for neutralizing chlorine (100 mg/l). The bactericidal action from zinc can be prevented by a small quantity of sodium phosphate in the sampling bottle.

Kichenko (131) stated that all varieties of coliform bacteria can serve as indicators of fecal contamination of water, while Burdin and Schmitt (38) recommended immunological differentiation of *E. coli.* When pathogenic *E. coli* are found, a single organism is enough to condemn a water source for drinking use. The identification of *E. coli* by production of indole after 48 hr incubation at 44°C was proposed by Buttiaux, Samaille, and Pierens (40). Clark *et al.* (55) and Geldreich *et al.*

(94) did not recommend boric acid lactose broth fermentation at 43°C in 48 hr and positive reactions in EC medium in 24 hr at 45°C as single specific tests for accurate identification of *E. coli* (++−− IMViC type); however, the tests did appear suitable for rapid enumerations of *E. coli* in the investigation of field problems and other kinds of control work.

In testing beach water samples for coliforms, Christovao (52) observed fewer presumptive and confirmed positives with lauryl tryptose broth than with lactose broth. Gabbrielli and Giunti (87) in comparative testing of media for enumeration of coliforms, found lauryl sulfate medium best. MacConkey medium was more selective and less sensitive than lactose broth. The Public Health Service Water Sub-Committee of Britain (184) did not recommend lactose glutamic acid as a satisfactory substitute for MacConkey broth, although the latter in the presumptive coliform test slightly suppressed both *B. coli* I and other true coliform organisms. Simpson and Cales (200) showed that brilliant green bile broth was slightly better than MacConkey broth in the 6-hr incubation period for the identification of *B. coli* type I and that indole broth was better than either MacConkey or brilliant green bile broth for rapid confirmation tests. Jameson and Emberley (124) suggested that the suitability of Teepol formulations, other than Teepol 530 and L, should be tested before use in culture media. The reliability of coliform density tests was evaluated by McCarthy *et al.* (150) who concluded that there is an enormous area for improvement in the estimation of the sanitary pollution parameter. A method is needed that will embody greater precision than the MPN procedure and that will also allow the cultivation and enumeration of all strains of the coliform group.

Kelly and Sanderson (129) reported that resistances of enteric viruses to chlorine exhibited differences according to strain rather than type. Strains in order of increasing resistance were *Coxsackie B 5*, *polio 1* (Mahoney), *polio 2*, *Coxsackie B 1*, *polio 3*, and *polio 1* (MK 500). Rises in pH value of one unit above pH 7 more than doubled the contact time required. Bacterial viruses, *E. coli phage T 2*, *S. typhi phage E 1*, *S. typhimurium phage 34*, and *S. sonnei phage IV* at pH 7.2 and 6°C were reduced 1,000 fold when exposed to 0.03 to 0.05 mg/l free chlorine for one minute (81), i.e., an amount of the same order of magnitude required for *E. coli*, *S. typhimurium*, and *S. sonnei*. The inactivation of *B. globigii* and *B. anthracis* spores by free available chlorine was markedly slowed by lowering the temperature or increasing the pH (34). To effectively inactivate bacterial spores, the reaction should be carried out at pH levels of 7 or less. Quantitative studies by Friberg (80) on the reaction of radioactive chlorine with bacteria in water disinfection showed that on an average, 10 to 25 per cent of the free available chlorine was found in the bacteria after 5 min exposure. Chang (45) has described the relative cysticidal and viricidal efficiencies of various chemical species of titrable iodine in water. Equations are given for computing cysticidal and viricidal titrable residual iodine in solutions of known amounts of iodine and pH.

Stumm (207) reviewed the production of ozone, its cost, chemical properties, solubility in water, and decomposition as well as problems of analysis. He indicated that ozone showed a more rapid action than chlorine in killing some of the more resistant organisms such as bacterial spores and cysts of *E. histolytica*. Three years' use of ozone in the disinfection of water for the City of Paris was detailed by Guinvarc'h (106). The rate of treatment averaged 1.1 mg/l and varied from 0.6 to 1.5 mg/l, depending on the pollution load of the raw

water. Treated water never showed the presence of *E. coli*, and in comparison with filtered water, *Cl. perfringens* was reduced 50 per cent.

A silver preparation "Micropur" was used with a peroxide compound in the disinfection of wells after pollution by flood water (162). Intermittent treatment of two to three doses showed definite disinfecting action even under unfavorable conditions. Reduced temperature and increased pollution decreased efficiency of the disinfectant. A modern Katadyn filter removed *S. enteritidis* and *S. thompson* from artificially infected water (151), but *Staph. aureus* and *Strep. faecalis* were not removed. Kristensen and Skadhauge (138) claimed that *Salmonellae dysentery* and cholera organisms in drinking water can be destroyed by hydrochloric acid in a concentration of 0.06 N after 10 min exposure time. The method is said to be unreliable for destruction of poliomyelitis and other viruses and for cysts of *E. histolytica*.

Chang *et al.* (46) (47) showed that temperature, pH, rate of stirring, buffering salts, and concentration of flocculent affected the removals of bacteria, *Coxsackie A 2* virus, and *Staph. albus* phage in water by flocculation with aluminum sulfate and ferric chloride. Under optimum conditions, 99 per cent or more of the viruses and bacteria were removed in the laboratory investigations. The critical time for formation of coagulant-microorganism complex in the removal of viruses and *E. coli* by practical dosages of alum at 25°C was confined to the first few minutes after addition of the coagulant.

Although Endo type media has certain disadvantages when used with membrane filter procedures, Roggen-Kamp (191) and Papavassiliou (173) obtained excellent results by careful attention to filtration and incubation techniques. Fifield and Schaufus (76) described an improved MF-Endo medium for enumeration of coliform organisms, which produced excellent, clear-cut sheen colonies in 20 to 22 hr incubation and did not require preliminary enrichment medium or incubation period. Lang (142) and Gohar and Eissa (98) found MF procedures superior to tube methods in the examination of "clean waters," but preferred titration methods for highly polluted waters. The Metropolitan Water Board of London (10), because of economic advantages and convenience, recommended MF procedures for the examination of selected types of samples. After comparing coliform counts in water by membrane filter and most probable number methods, Akman (2) concluded that it was not advisable to depend on MF procedures alone; however, the filters used were several years old and not of type and quality currently available.

Jones (126) discussed the use of membrane filters for the examination of potable water for the U. S. Air Force. Nine significant advantages for the membrane filter versus five disadvantages of using the MPN methods were given, indicating the high desirability of adopting the MF field kit as a water testing device. In November of 1957 the American Water Works Association accepted the membrane filter procedure as an alternate to the completed tests when specified conditions were met (9). Hazey (112) presented an operator's viewpoint of the MF technique and concluded that the daily bacteriological examination was more interesting and became a pleasant assignment. The ability to count actual colonies has more meaning to the operator than an estimated number from a table.

Slime Growths

Sphaerotilus and associated slime bacteria may be found in streams in many parts of the world but frequently escape notice when existing as free organisms in low density. However,

under selected environmental conditions and in the presence of relatively low concentrations of domestic sewage or industrial wastes, sudden explosive growths may occur in a stream. These growths appear as attached or floating plumes or masses of dirty colored material. They rapidly accumulate in sufficient quantity to decrease the usefulness of the stream for recreational use, produce an unsightly appearance, disturb aquatic life, and lead to the development of sludge banks downstream. The anaerobic decomposition of such sludge banks can produce offensive conditions many miles from the place of the original growth. When the growth reaches a nuisance level, it is properly described as a *Sphaerotilus* infestation. These infestations may occur periodically, occasionally, seasonally, or for long periods in a chronic condition. Such infestations present formidable control problems in many streams.

The best current review of slime infestations by *Sphaerotilus* and *Leptomitus* is the report by Harrison and Heukelekian (109). This paper is highly recommended for the detailed summary of problems, methods, morphology, taxonomy, nutritional requirements, mineral needs, and the known environmental effects on the *Sphaerotilus* and *Leptomitus*, plus the citation of 52 references in the text and an additional 32 references by title. It serves equally well as a valuable review for the experienced worker and as a basic introduction of slime infestation problems and methods for those newly undertaking investigations in this field.

Considering the nuisance problems created in streams in many parts, there have been remarkably few reports in the current year's technical literature. Perhaps this emphasizes the difficulties encountered in the investigation of the causes and control of slime infestations in streams.

Cawley (44) made a careful investigation of an infestation occurring in the downstream area from a paper mill outfall on the Altamaha River in Georgia. The *Sphaerotilus* did not reach nuisance levels until the mill had been in operation approximately 18 months. The organism, identified as *Sphaerotilus natans*, was studied in the stream environment and in the laboratory on media containing the organic compounds found in the waste. Control of the growth by intermittent discharge of waste for 8 to 10 hr/day reduced the growth but did not prevent it even when timed to begin after the river had cleared following a mill shutdown. After the growth had been established in the river, a trial run of intermittent discharge of 12 hr/day of waste had no appreciable control effect. Growths in this river were affected by DO, short-chain organic compounds, temperature, pH, and flow rates. It was also recognized that unknown environmental factors exist which markedly affect the infestation, and at present no satisfactory theory can be developed to explain growths of *Sphaerotilus natans*.

Streams in Germany receiving paper mill wastes or wastes containing short chain alcohols frequently developed infestations with *Sphaerotilus natans* as the predominating organism according to Höhnl (117). This investigator was of the opinion that, in addition to the usual organic and inorganic nutrients and suitable environmental conditions, 18 amino acids and a sugar content of 20 to 50 μg/l were necessary for growth. *Sphaerotilus natans* was present in pH ranges of 5.8 to 9 and *Sphaerotilus dichotoma* at approximately pH 6.4 but when the pH range reached 5.2 to 5.6, the predominating organisms were species of *Fusarium* and *Mucor*. Use of chlorine at the maximum permissible concentration in streams (1 mg/l) was not effective as a control measure.

Pooth (180) reported an infestation in a Swedish stream receiving wastes from a wood fiber plant. The predominating organism was *Achlya pro-*

lifera immediately downstream which was replaced by *Leptomitus lacteus*. The simple sugars contained in the factory waste were presumed to be the main source of nutrients which upset the biological balance in the stream. The author believed pure culture studies on different nutrient substrates might give the reason for the mass growth.

Sphaerotilus and *Leptomitus* species were considered by Wurtz (232) to be indicators of organic pollution in the stream since growth can only occur in the presence of organic acids, a good nitrogen source, and mineral salts. Infestations occurred in French streams polluted with wastes from milk processing plants, sugar refineries, or distilleries. The *Sphaerotilus natans* appeared in more polluted streams while less pollution usually produced another physiological form known as *Cladothrix dichotoma*. One stream was described which received sugar wastes that had the *Sphaerotilus* give way to the *Cladothrix* toward the end of refining operations.

Becking, Ferguson, and Kaplan (24) report a pH limit of 4.6 to 8.0 and an E_h limit of 200 to 500 v for growth of the genera *Sphaerotilus* and *Gallionella* in estuary studies.

Wolfe (230) cites the work of Pringsham showing iron can be deposited in the *Sphaerotilus natans* sheath but holds the opinion that it is extremely doubtful if the organism can actually utilize the energy of iron oxidation. Skerman, Dementjera, and Carey (202) in similar work with sulfur demonstrated the deposition of sulfur granules in sheathed *Sphaerotilus natans* when grown in an atmosphere containing H_2S but express doubt that the engorged cells are viable.

Probably the outstanding report of the year from a practical control viewpoint was presented in the Progress Report of the Columbia River Study 1956–1958 (16). Tentative results of this investigation suggest the phosphorus concentration appears critical in limiting growth in systems containing above minimum concentration of ammonia-nitrogen; abrupt increases in flow velocities increase floating masses downstream; dry sulfite solids of 5 mg/l support growth and may occur at 1.3 mg/l; nitrogen and phosphorus essential for growth are not present in spent sulfite liquor; and, intermittent discharge on a 1-day discharge with two or more days holding was an effective control measure in laboratory experiments while 12 hr discharge and 12 hr holding time were ineffective.

Summary

Slime infestations by *Sphaerotilus natans* and associated bacteria may occur in relatively good quality waters where wastes are received from wood processing plants, paper mills, milk processing plants, sugar refineries, or distilleries. These infestations have many common characteristics but there are others that are unique to the individual stream. There is no doubt of the existence of unknown environmental conditions which are of major importance in determining whether an infestation will occur in a specific stream. The slime bacteria have voracious appetites for a variety of organic substances in various substrates. Satisfactory control measures applicable to streams have not been developed. Intermittent discharge of 12 hr and 12 hr retention has little or no value in stream control. Laboratory experiments using a 24-hr discharge schedule with a 2- to 5-day retention period between discharge appears to offer some promise of success.

Chemistry

Facets of BOD and laboratory estimates of actual stream BOD received consideration as usual. Chase and Ferullo (48) found water-logged leaves to exert a substantial drain on stream oxygen resources under aerobic conditions, and the long-time BOD of maple

leaves was reported to be 75 per cent of dry weight; while for oak leaves and pine needles, the corresponding figure was approximately 50 per cent. Gaffney and Heukelekian (88) reported exhaustive studies of the BOD of the lower fatty acids. Oberton and Stack (161) catalogued factors of importance in making significant laboratory measurement of the BOD of industrial wastes. Ettinger (74) attempted to generalize on factors common to biological oxidations.

Resnick *et al.* (188) reported they were unable to convert cyanate into cyanide by irradiation or by addition to anaerobic substrates.

Bunch and Barth (36) presented studies of the possible use of immunological procedures for the detection of fermentation wastes. Using antisera prepared against *Penicillium chrysogenum, Streptomyces lavendulae,* it was shown that microgram amounts of metabolites from these organisms could be added to river water, recovered, and detected.

Oxygen Sag and Stream Self-Purification

Proceedings of a seminar on oxygen relationships in streams included a number of papers and new items of general interest. The several well-known approaches to selection of the necessary degree of waste treatment by analysis of oxygen relationships in the stream were ably presented and discussed. Dappert (65) discussed the applicability and use of stream data in the administration of a pollution abatement program with special attention to the use of "rule-of-thumb" techniques for the decision on waste treatment requirements. He emphasized the frequent need for decisions in the absence of adequate stream data and the importance of the use of judgment based on knowledge of the local circumstances in each case. It was brought out in his paper and in the following discussions that in a major pollution abatement program involving many communities and industrial waste sources, the limitations of available personnel, funds, and time make it virtually impossible to accomplish exhaustive analyses in each case in terms of the oxygen sag theory. It was felt that, in view of these circumstances and the long-range objectives of the abatement program, considerable satisfactory progress had been made.

Streeter (204) reviewed the general oxygen sag theory, bringing it up to date and indicating its usefulness today. Its limitations were pointed out, and also some of the simplified approaches to the oxygen balance problems were discussed, with their limitations. O'Connor (163) presented a detailed review of the theory of atmospheric reaeration, together with the new approach to prediction of the reaeration velocity constant, k_2, based on the theory of isotropic and non-isotropic turbulent flow. One area of some confusion still exists in this problem of determination of the rate of atmospheric reaeration, namely, that in field studies it is most difficult to separate the effects of photosynthesis in stream reaches where algae occur in significant numbers. In effect, while reaeration rates may be measured under laboratory conditions, in the field what is really measured is a reoxygenation rate because of the effects of photosynthesis. Thus, the direct comparison of rate constants as determined in the field with rate constants computed on the basis of a theory of atmospheric reaeration remains somewhat in question.

The application of existing theories to the problem of estimating oxygen demands from river deposits of organic material was reviewed and discussed in detail by Velz (221). This paper contains an excellent review of the subject of sludge deposits and demands, together with practical examples illustrating the application of the theory earlier proposed by Streeter and illustration of

some of the finer points of application.

Gameson and Barrett (90) gave a detailed review of the results obtained by British workers in recent years, illustrating many of these results in the example of the Thames Estuary. This discussion included specific information and results on the solubility of oxygen in sea water, the relation between the BOD and the UOD (Ultimate Oxygen Demand), tidal mixing, and the exchange coefficient for reaeration. Considerable information was presented regarding factors that affect the reaeration exchange coefficient, as well as a method for direct measurement of the exchange coefficient in the field. Thomas (216) offered a discussion of the mixing and diffusion of wastes in streams. Definitions and equations describing the processes involved were presented, with emphasis on longitudinal mixing. The effects of stream impoundments on the oxygen resources were discussed by Churchill (53). Detailed discussion of the hydraulics of reservoirs and the problem of thermal stratification was included, together with point-by-point indication of the effects on dissolved oxygen.

The problem of obtaining truly representative samples and satisfactory data from field studies was discussed by Haney and Schmidt (107). It was emphasized that, before sampling is started, objectives of any survey should be clearly defined and sampling should be planned logically on the basis of these objectives. Some of the factors discussed in this paper included: (a) the effects of river flow and the importance of obtaining samples under conditions of steady runoff; (b) the location of sampling points relative to sources of pollution; (c) the physical characteristics of the stream, including the location of power dams and impoundments; and (d) other conditions involving abnormalities of natural self-purification. Some discussion of the importance of adequate analytical procedures was also presented, as well as the need for continuous automatic sampling and recording equipment.

Schroepfer (195) discussed the application of stream survey data to waste treatment plant design, and illustrated a statistical approach with data applying to the Minneapolis-St. Paul situation. Thousands of analytical results were interpreted by statistical methods using the equation

$$DO_a - BOD_{ab} - BD_{ab} - DO_{tp} + R_{ab} = DO_b$$

for any stretch of river between the points A and B. DO_a and DO_b refer to the observed DO values at the upper and lower end of the stretch, BOD_{ab} refers to the amount of BOD exerted in the reach, BD_{ab} represents the oxygen demand of benthal deposits within the reach, DO_{tp} includes the effects on the oxygen resources of thermal pollution, and R_{ab} refers to the oxygen income from reaeration and photosynthesis within the reach. The use of such an equation and approach proved especially valuable in the case illustrated, which involved a large capital investment for waste treatment facilities. Wisniewski (228) presented considerable information regarding the effects of algae on dissolved oxygen and BOD in the laboratory and in streams. Further information on this subject was recorded during the discussion period.

A closing panel discussion of areas for future research was of considerable interest. Spies (203) indicated the need for fundamental studies of the development of slime growths in the presence of certain industrial wastes and their effects on the stream, as well as a need for investigation of the damaging effects of excessive turbidity in streams. He also indicated the need for information regarding the effectiveness of patented waste treatment processes, and the importance of developing continuous and automatic samplers. Pearson (176) indicated the need for fundamental studies of the role of turbulence and other physical

factors in stream natural self-purification. He also discussed the importance of better methodology, especially with regard to the biological processes, and called for information leading to a quantitative description of the biota so that this information might be applied in engineering estimates. The growing importance of estuarine problems of pollution and the need for developing adequate approaches to this problem were also pointed out. A need for further study of the effects of thermal pollution was indicated by Schroepfer (196), who also called for studies leading to a reappraisal of the course of deoxygenation and the effects of temperature upon this process. He also emphasized the desirability of a continuous DO recorder. Kittrell (134) discussed the effects in streams of nitrification and indicated the need for further studies on this subject. He also indicated the importance, especially in small streams, of the absorption of BOD by biological slimes, and the possibility of storage of this organic material indefinitely by such slimes without attendant oxygen demands on the flowing stream. The occurrence of initially high BOD velocity constants was also indicated, together with the desirability of learning more about this phenomenon.

The ultimate oxygen demand (UOD) of sewage effluents and the course of oxidation are discussed in some detail in a recent paper by Gameson and Wheatland (92). The UOD has been computed on the basis of the organic carbon and nitrogen content of the sewage according to the following equation:

$$\text{UOD} = 2.67\ (\text{organic carbon}) + 4.57\ (\text{ammonia nitrogen} + \text{organic nitrogen}) + 1.14\ (\text{nitrous nitrogen}).$$

This equation is believed by the authors to be quite general and may be used for estimates of the UOD in any case. Several examples are given and the course of the BOD reaction has been analyzed according to several possible mathematical hypotheses. Discussion is presented of the possible bases for the above formula for UOD and for the hypotheses regarding the course of the BOD reaction. Truesdale and Vandyke (218) have reported on their studies of the effects of temperature on the rate of aeration of flowing water. In terms of the exchange coefficient, as developed by the British workers, a change of 1.5 per cent per degree Centrigrade is indicated as the average result. Some difficulties were encountered in this work and further work is reported to be in progress. Downing *et al.* (71) have also indicated the effects of various pollutants on the rate of reaeration of water. Measured in terms of the exchange coefficient, mixed household detergents reduced the rate of reaeration in clean water by amounts depending on the concentration of detergents. The effects of sewage effluents were similar to those of mixed household detergents but, in the absence of anionic surface-active agents, the effects of sewage effluents were substantially less.

Studies by Oldaker (166) of organic sludge deposits in the Connecticut River indicate the importance of recognizing the large oxygen demands that may result from the presence of such deposits. Moore (156) has reviewed the effects of discharge to streams of heated water (thermal pollution) in terms of the effects on oxygen resources and on the oxygen sag. Data are presented and parallel graphing of water and air temperatures of a small stream having no thermal pollution, an intermediate-sized stream having a high thermal load with resulting damaging effects, and a large river having a high heat input but good recovery. Results of a study to evaluate the aeration of streams at power turbines are presented by Scott *et al.* (197). Data indicating the improvement in downstream DO conditions were col-

lected in connection with the introduction of air by diffuser tubes and by venting turbines, and compared to base studies in which no air was introduced. The amount of oxygen absorbed by the water in passing through the turbines was dependent on the influent water oxygen deficit and the rate of air admission. It was also determined that stream aeration by means of turbine venting yielded better results than aeration by the use of a compressor and air diffusion through tubes and plates.

A nomograph facilitating exact solution for variables of the Streeter-Phelps oxygen sag equation has been prepared by Wastler and Wastler (223). Using two resistance-capacitance circuits, Sinkoff *et al.* (201) have developed an electrical analog computer for the oxygen sag curve which permits a wide variety of rapid computations involving the oxygen sag equation.

Churchill (54) has outlined the plans and course of present studies on the development of a mathematical formula for predicting the rate of reaeration in river reaches. Field studies are being carried out in reaches devoid of pollution. Reaeration rates thus determined are to be related to the physical characteristics of the reach on the basis of a dimensional analysis of the many parameters involved and the use of a statistical multiple regression technique. It is hoped to indicate the relative importance of the many physical factors and to develop a simplified dimensionally-consistent equation for practical application.

As a result of experiments with various organic compounds, Bogan (30) indicates that the BOD and COD, while valuable measures of one form of stream pollution, are not adequate measures of all organic stream pollution. Neither test, it is stated, describes or identifies residual persistent organics that remain after partial biochemical oxidation. Intermediate products or by-products of biochemical degradation of oils and of alkyl benzene sulfonates are demonstrated in a series of experiments. The conclusion is drawn that oxidation may involve only a portion of the original molecule. The evidence also indicates that many consecutive enzyme reactions may be involved in the degradation of an organic chemical, these reactions taking place at rates which may be widely different. Certain of these enzyme reactions may regulate the total rate at which a substance can be oxidized. Other experiments involving oxidation rates of condensed phosphates in dilute solutions have been reported by Karl-Kroupa *et al.* (128).

Beneden (25) has performed a number of experiments involving the question of whether BOD is actually a measure of the pollution load or of the bacterial activity. These experiments consider the effects of organic nitrogen concentration, seeding, and dilution as well as the effects of additions of amino acids and large nitrogen molecules. Leclerc *et al.* (144) have reported on their investigations of the Geer River in Belgium to determine self-purification capacity. The Geer was subject to seasonal pollution. Pöpel and Hunken (181) have developed a load distribution chart for permissible loads on rivers, minimum flow requirements, etc., on the basis of self-purification analysis. Pien (178) has described the application of natural self-purification principles in rivers polluted by milk wastewaters.

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Stream Studies and Surveys

This year several papers have stressed the importance of collecting basic water quality data from the Nation's waterways. There is still an apparent lack of many fine survey studies reaching formal publication, thus preventing their review here. An extreme effort should be made to encourage publication.

Three papers by Palange and Megregian (171) (172), and Green (102) describe the cooperative USPHS water quality basic data program and its significance. Examples have been given of what water quality data developed on a nationwide basis can show. It is indicated that a program of this type would provide "intelligence service" rather than monitoring or surveillance. It should provide the means for continuous evaluation of the quality of water resources so that when any necessary corrective action is indicated, a warning or "alert" can be flashed. This warning should designate the general area needing relief and the degree of correction necessary. The basic data program is not intended to and should not take the place of detailed field surveys required for the solution of local problems.

The Federal network will provide data for interstate and international streams and for areas affected by Federal installations. These data will be issued annually in a government publication available to all. It is hoped that the states and other local agencies responsible for water resources will develop intrastate programs which can be linked with the national network, with the Federal stations used as reference points.

In addition to the principal benefits to be gained through the collection and publication of these fundamental data, the program has already stimulated activities at many water plants. This activity has resulted in more comprehensive laboratory coverage and increased utilization of the newer parameters for assessment of water quality.

It is presently anticipated that the USPHS responsibility can be adequately covered by a maximum of 250 to 300 stations. When supplemented by intrastate programs, these should provide the data necessary for all future efforts aimed at the preservation and maximum utilization of the Nation's water resources.

Cleary (57) has published a paper stressing the desirability of collecting "vital data" and their value for water resources development programs. Cleary and Robertson (58) have described the modest beginning of the ORSANCO program, starting with 11 Ohio River Stations in 1951 and augmenting the network to include 43 locations today on the main stem as well as tributaries. A robot monitoring station project is discussed, considering the feasibility of adapting analytical instruments for continuous recording and automatic transmission of river quality data.

The Severn River Board in England (18) points out that no significant changes have occurred in any stream that is under their jurisdiction. Data indicate that rivers are holding their own as far as pollution is concerned, which is heartening in view of industrial expansion. Michalski (154) in discussing analyses for contaminants in water states that chemical, physical, and biological data are equally important in determining the extent of pollution of surface waters. Interpretation of results should be made by both limnologists and sanitary engineers, with support given by specialists in the fields of industry, agriculture, fish culture, public health, etc.

Beak (22) discusses the joint approach of chemical engineer and biologist in investigating industrial water pollution problems. Biological back-

ground of the BOD test and interpretation of results are outlined. Oxygen profiles, reaeration, and self-purification are considered.

Field investigations of the Connecticut River by Oldaker (165) involved experiments that revealed the rate of accumulation of bottom deposits and their relationship to oxygen demands which may be exerted at various stations. Tsivoglou *et al.* (219) reported results of surveys on streams receiving radioactive wastes with long half lives from uranium ore refineries on the Colorado Plateau. Need for future research is stressed. The gross radioactivity and soluble radium content of waters downstream from mill effluents were found to be in excess of the usually accepted maximum permissible amounts. There was evidence of iridium and other radioactive elements in river muds and biological samples below mills. Swain and Newman (209) presented data from a hydrographical survey of the River Usk undertaken to determine the effect of cooling water from an electric power generating station on the condition of the river, specifically on salmon fisheries. They report that there have been no significant changes in the river. Salomonson (194) reports field studies of the drainage at Kyr Kebyns Bruk, Sweden, to reveal the effects of spent sulfite liquor. He reports that the polluting effect was not serious except in a strait between two lakes. On two occasions fish mortality occurred when weather conditions were particularly unfavorable for disposal of large volumes of waste liquor. The liquor in the future is to be evaporated and burned so no further pollution will occur.

An anonymous report (13) discusses the distribution and stratification of sulfite "dyes" in the Bleiloch Reservoir. Investigations revealed that pollution of the impounding reservoir is caused by wastewaters from a sulfite cellulose factory. Water of the Saale flows through the reservoir in autumn and winter as a bottom stream in the old river bed; in spring and summer the water flows according to the thermal stratification, as a layer parallel to the surface at depths of 2 to 10 m over the whole width of the reservoir. It mixes very slowly with water below and above and causes a rapid oxygen demand in the metalimnion and epilimnion; the hypolimnion is mainly unaffected. Even in a year of normal rainfall the self-purifying power of the reservoir is insufficient to deal with the pollution load, and conditions deteriorated with the low rainfall at the end of 1953 and the beginning of 1954.

Gameson *et al.* (91) discussed the effects of heated discharges on the temperature of the Thames estuary. Their paper provides data for a rapid method of estimating the changes of temperature which would follow any alteration in the amount or position of discharged heat. Burt and Marriage (39) have investigated the Yaquina River estuary to determine the possible distribution of pollution from a proposed pulp mill. Salinity observations from the ocean to a point 20 miles upstream were made during low and high flow periods. Graphs show expected distribution for summer and winter conditions. The results of this study may be used as a guide for future pollution investigations in West Coast tidal estuaries which are similar to the Yaquina.

Representative sampling and analytical methods in stream studies received sound attention by Haney and Schmidt (107). They indicate that if a sampling program is not carefully planned and the analyses accurately conducted, no matter how the data are manipulated graphically and mathematically, or how elegantly the report of findings is presented, the end result will be weak.

Technical Report W58–2 (14) issued by the Public Health Service on a seminar, "Oxygen Relationships in Streams," contains the complete program of the seminar including the papers, formal discussions, and informal

discussion. The topics presented include the use of stream data in field investigations, mixing and diffusion, reaeration, effects of impoundments, sampling, and the application of stream data to waste treatment plant design. Issued as a companion piece to this volume was a reprinting of the historic and classical document of Streeter and Phelps entitled "A Study of the Pollution and Natural Purification of the Ohio River," initially published in 1925, which has been out of print for many years (205).

Stream Standards

The perennial question of effluent versus stream standards was renewed by the Association of British Chemical Manufacturers through their technical executive officer (15). This report expressed the vital interest of the manufacturers in water conservation and in cooperation for pollution control. It pointed out that effluent standards are likely to be based on drought flows and may require rigidly excessive and costly treatment much of the time when stream flows are higher than minimum. Stream standards, on the other hand, allow flexible adjustment of waste discharges to varying stream discharges and permit optimum use of the natural purification capacities of streams. While fixed stream standards have not been adopted there is general acceptance, as guides, of: a maximum limit of 4 mg/l of BOD; pH in the range of 6.0 to 9.0; suspended solids that will not cause silting of streams; and virtually complete removal of highly toxic substances such as cyanides and certain metal ions. The needs for more study and research on streams, wastes, and analytical methods, and for tailoring standards to the needs of the individual situation are emphasized.

The New England Water Pollution Control Commission, established by Compact, uses an extremely flexible set of stream standards. Knox (135) notes that this flexibility permits the individual states of the Compact group to retain their own standards and still comply with the intent of the Commission standards. The Commission has adopted four classes of satisfactory water quality ranging from Class A, suitable for any water use, to Class D, suitable for transportation of sewage and industrial wastes without nuisance. Quantitative values are expressed for only two constituents. DO shall not be less than 75 per cent saturation for Classes A and B, and in concentration not less than 5 mg/l for Class C. Class A sea waters for market shellfish shall not have a median coliform content in excess of 70 per 100 ml. Other standards are expressed in such terms as "none," "no appreciable amount," and "not objectionable."

Cherkinsky (49) proposes a theoretical basis for hygienic standardization of water courses receiving combinations of several harmful substances with similar noxious properties, such as smell, taste, and toxicity. The value of the maximum permissible concentration of each substance should be reduced by a factor equal to the number of similar substances in the wastes, and the sum of the concentrations of all such substances, expressed in per cent of the maximum permissible concentration for each substance, should not exceed 100 per cent.

Effects on Water Supplies

Metzler *et al.* (153) report on the experiences at Chanute, Kansas, where from October 1956 to March 1957 the city was obliged to use treated sewage as its water supply because of an extreme and prolonged drought period. The deterioration in chemical quality was traced throughout the period. Bacteriological quality remained good.

Detergent pollution of ground water in Suffolk County, New York, is discussed by Flynn *et al.* (79) in an area where individual wells and cesspools are installed on 60- by 100-ft lots. Regulations requiring larger lots for such

installations have been adopted by the County Health Department (8).

Tastes and odors continue to be among the major effects of pollution on water supplies. Guinvarc'h (105) reports on experiences in France and notes the frequent occurrence of difficulties on weekends because of industrial discharges at those times. Carter (43) discusses problems in the London Metropolitan Supply. Ettinger and Rosen (75) review the work done at the Robert A. Taft Sanitary Engineering Center on trace organics in water, their odor characteristics, variations in response of odor panel members, etc. Campbell *et al.* (42) studied the effect of certain chemicals in water on the flavor of brewed coffee. Taste thresholds were determined for ammonia, Calgon, chlorine, orthochlorophenol, parachlorophenol, disodium dihydrogen versenate, hydrogen sulfide, phenol, Tide, and trisodium phosphate.

Abatement and Control

Reports from several sources during the year reflect the progress or lack of progress being made in the United States to abate pollution of principal waters.

The Engineering News-Record (7), in reporting on "Where We Stand on Pollution Control," a resume of USPHS inventory on municipal sewage treatment facilities, points out the progress being made in this area. The population served by treatment plants increased 38 per cent during the period 1953–57. This is compared with 8 per cent for each of the previous 4-yr periods following 1949. Furthermore, populations served by secondary or complete treatment increased 66 per cent between 1949 and 1957. The disturbing note in the picture lies in the fact that in spite of the increase in volume of treatment plant construction, there has still been a slight increase in the pollution load from community systems discharging into the Nation's waters.

Ransom (185) has summarized the accomplishments in Ohio over the past 10 years and estimates that a total of ¼ billion dollars, including projects now under construction, will have been put into new and rebuilt plants in that state.

Other indicators of progress come from Kansas (11) where the State Board of Health reports improved water quality in the Little Arkansas River due to better brine disposal practices. The most effective remedial measure appears to be the reintroduction of brines into underground formations.

Morgan (157) reports progress being made in reducing the mine acid load in Pennsylvania's streams. With the tremendous increase in strip mining during the past 30 to 40 years, the major efforts of the control agency have been directed at control of these operations. Some of the recommended practices are:

1. Use surface water diversion ditches to keep water out of strip mines.
2. Collect ground water and channel it by conduits through backfilled strip areas.
3. Don't strip across stream channels, thus leaving stream banks intact to protect natural channels in strip mine areas by hedge-hopping streams.
4. Control seepage from strip operations by leaving overburden undisturbed at the outcrop of the coal.
5. Backfill strip pits promptly to reduce the time sulfuritic material is exposed to air and moisture.
6. Prevent seepage into sulfuritic material by segregating gob or coal-bearing waste in backfill and sealing it off with impervious cover.

The spreading of the pumping from deep mines over longer periods than now used would even out the acid discharges to streams so that acid conditions would not exist in many areas. It is estimated that if pumping from deep mines were spread over 24 hours

instead of much shorter periods there would be no acid conditions in the Ohio River below Pittsburgh.

A summary of the Oregon State Sanitary Authority's 1957 Progress Report (12) states that the stream pollution fight in that State is far from won. The Willamette River pollution was worse that year than during the previous three years due to low stream flow conditions.

Covill (64), in discussing water pollution problems in Great Britin, indicates their problems are not much different than those experienced in this country. He cites overloaded sewage treatment plants, inadequate operating personnel, insufficient removal of synthetic detergents, storm water discharges, increasingly diverse and complex array of industry effluents, and increasing use of agricultural chemicals as constituting some of the principal problems in that area. He discussed each of these subjects in some detail.

The Chemical Industry Committee of ORSANCO (123) reports on the importance of considering waste disposal problems in the selecting of sites for chemical plants. The report emphasizes the desirability of supplying water pollution control agencies with available information regarding waste problems of proposed industries. Early cooperation between industry and regulatory agencies is essential for intelligent and wise planning.

Descroix (70), in discussing "The Problem of Water in Germany," states that Germany has passed a new water law imposing controls on the use and discharge of waters. It provides effluent standards and completely outlaws certain discharges.

Kempf (130), in discussing proposed revisions to French stream pollution legislation points out that the new legislation is somewhat more realistic than that previously in existence which stemmed from an 1829 statute intended to prevent poaching and which provided for one to five years imprisonment for releasing anything injurious to fish in the streams. The new law reduces the penalty but also provides for requiring industries to install treatment facilities where necessary.

As reported by Kyle (140), 10 river purification boards are planned for Scotland. Duties of the boards include the promotion of water cleanliness and conservation of water resources. The boards are authorized to make surveys, to engage and complete records of runoff, and they have a right to enter and inspect any plant or facility of water users. Notification of the industry and splitting of samples are required if the analytical data are to be admittable as evidence.

As progress in the construction of abatement works continues and as water uses expand more and more, attention is being given to monitoring water quality by regulatory agencies. This provides a check on the adequacy of treatment works and also supplies essential information on the effects of various pollutants on water quality.

Cleary (56) reports on the progress being made by ORSANCO in operating a network of 43 monitoring stations to provide a continuing record of information to aid in the diagnosis of stream conditions in the Ohio River. Personnel from public and private water works plants situated at various points on the Ohio River constitute the "Water Users Committee" of the Commission. Personnel from these plants collected samples at regular intervals for various examinations including the usual mineral analyses, plus other special determinations such as coliform organisms, radioactivity determinations, and determination of organic compounds.

Palange and Megregian (172) also report on the activities of the Public Health Service in establishing a program for collecting basic data on water quality. During the first year under this operation 50 water sampling stations were established on the Great

Lakes and interstate streams of the United States. At each of these stations samples of raw water are collected and analyzed for radioactivity, plankton population, coliform organisms, and the conventional physical chemical analysis. This program also relies on cooperation of various state and regulatory agencies, especially water treatment plant personnel located at sampling stations. The ultimate objective is to develop an integrated Federal-state-local network giving adequate coverage to waters of the Nation.

Krause (136) discusses the Public Health Service study in the Arkansas and Red River Basins designed to define the sources of natural and artificial brine pollution and to formulate methods for making more of the waters in the area usable. High salinities in certain streams of these basins have long been a problem even before artificial pollution added its contribution. Preliminary investigations indicate that substantial improvement in the quality of some streams appears feasible. The study further points out the importance of basic water quality data in defining water quality needs and appropriate pollution preventive measures.

Hopkins and Neel (119) discuss the effects of impoundments on water quality in the Missouri River and point out that both beneficial and detrimental effects can result.

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32nd ANNUAL MEETING

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Host — Texas Water and Sewage Works Association

Dallas, Texas — Statler Hilton Hotel — October 12–15, 1959

Meeting Sessions and Exhibits — Dallas Memorial Auditorium

Sewage Works

PERFORMANCE TEST OF CONTINUOUS RECORDING DISSOLVED OXYGEN ANALYZER

By M. O. Macklin, D. J. Baumgartner, and M. B. Ettinger

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Work has been underway since 1953 to develop an instrument for continuous analysis of dissolved oxygen in water. Preliminary investigations indicated that the principles contained in the theory of aeration and Henry's Law of solubility for inert gases in water offered a physical basis for instrument development. Subsequent work by Levine and Kleinschmidt (1) and Levine *et al.* (2) resulted in a prototype system consisting of an aspirator, a gas-water separator, an oxygen-gas analyzer, a recorder, and a supply of nitrogen. The aspirator equilibrated a stream of the water to be analyzed with a small volume of gas to yield a gas having an oxygen content related to that of the water stream analyzed. Nitrogen was used to maintain a constant pressure in the system.

Requirements for a Functional Unit

Since the prototype indicated promise of successful application, a contract to engineer and build a functional field instrument was negotiated with the Hays Corporation in December 1957. Main objectives for the instrument as set forth in the contract were:

1. The instrument should be capable of recording the per cent saturation of DO in the water within ± 5 per cent of the true value in the range of 0 to 150 per cent. Waters containing up to 2,000 mg/l suspended solids and up to 300 mg/l COD were to be analyzed.

2. The instrument should show 90 per cent response in reading in 20 min or less for any arbitrary change in oxygen content. For further explanation of 90 per cent resolution see (2).

3. The instrument should be portable and, if possible, should be comprised of units weighing less than 100 lb each.

4. The instrument should not be subject to clogging and should not require electrical or mechanical readjustment or calibration at intervals of less than 48 hr.

Apparatus Used

A model of the instrument was finished in August 1958. It consisted of a pump, a system for aspirating and separating the gas and water, and a standard commercial apparatus * for analyzing gases for oxygen, modified to read in per cent saturation. The pump was a positive displacement type, was pressure-tested for leaks, and was capable of delivering 4 gpm. Since the capacity of the aspirator-separator system was 1 to 1.5 gpm, the pump was equipped with a bypass. A regulator maintained a pressure of approximately 50 psi ahead of the aspirator.

Details of the aspirator-gas separator system are shown in Figure 1. Water

* Hays Corporation, Michigan City, Ind.

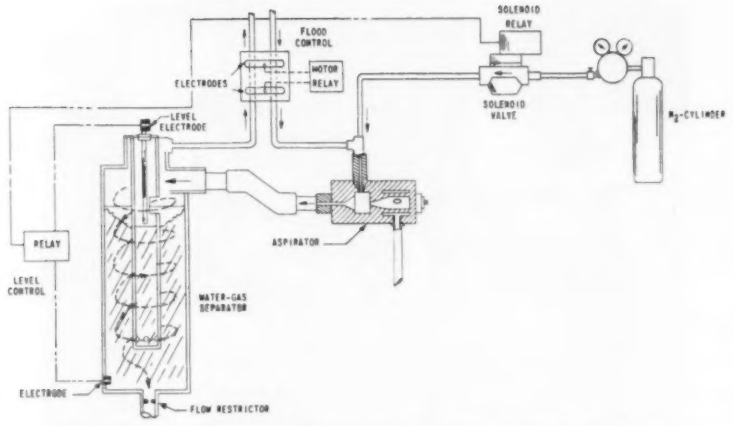

FIGURE 1.—Schematic diagram of aspirator-gas separator system.

enters the inner section of the aspirator tangentially and is expelled from a narrow aperture in the end of the cone-shaped discharge section. This action draws the gas into the aspirator and intimately mixes it with the water on the way to the water-gas cyclone separator. Here again the mixture enters tangentially and the gas is separated from the water by centrifugal force. An inner stilling tube equipped with an electrode system connected to a

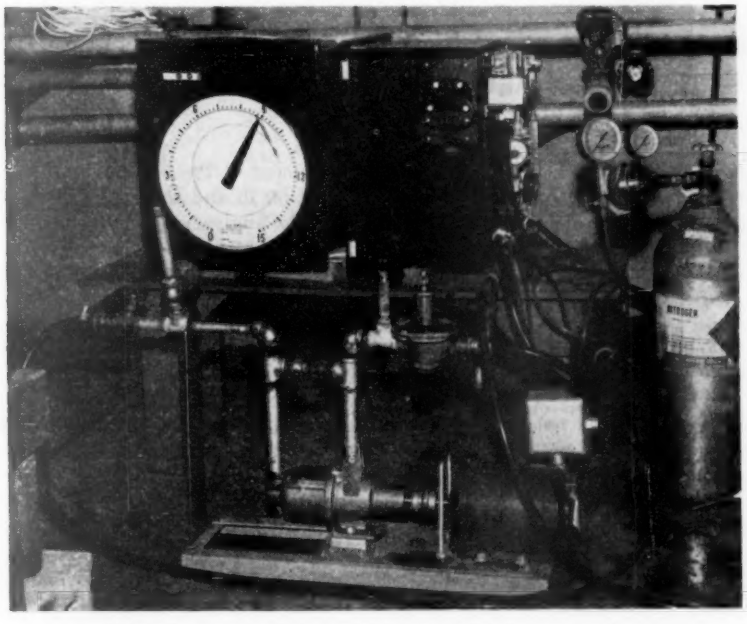

FIGURE 2.—Equipment used for dissolved oxygen analyzer.

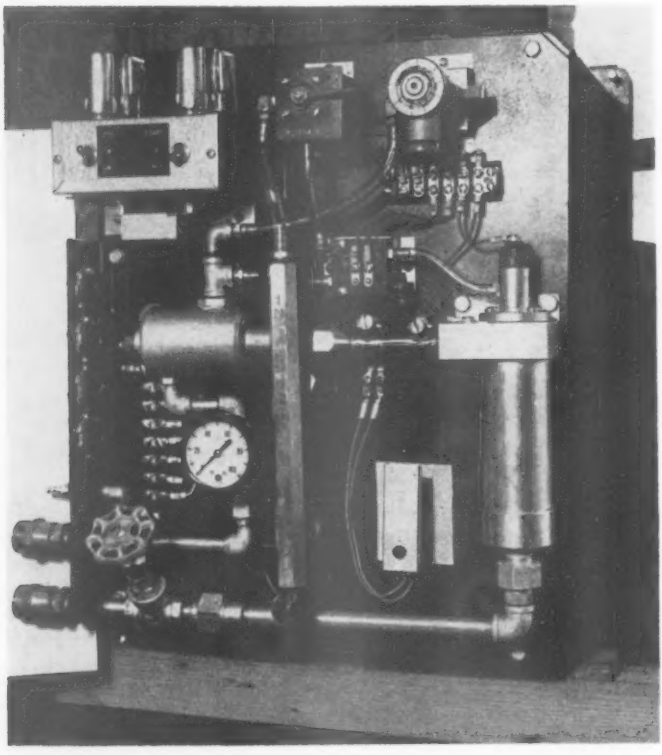

FIGURE 3.—Aspirator-gas separator system used in dissolved oxygen analyzer.

nitrogen cylinder feeds nitrogen, as required, to maintain the water level at the tip of the level control electrode. The water leaves the system through an orifice which provides a pressure of about 3 psi in the gas system when the pressure of the water fed to the aspirator is held at 50 psi.

The gas leaving the separator is forced through the oxygen analyzer where the amount of oxygen is determined. The gas-analyzer feed line contains a "fail safe" device consisting of two electrodes which shut off the pump motor if the circuit is closed by water drawn into the line by the recirculated gas.

Figure 2 indicates the size of the units and the space required for the equipment. The pump unit weighs about 50 lb and the recorder about 60 lb. The analyzer, including the aspirator-separator system mounted on the rear (Figure 3) weighs about 100 lb. Any size cylinder of water-pumped nitrogen may be used. The reducing valve must be fairly sensitive and accurate. It should supply nitrogen to the system at about 0.5 psi higher than the pressure in the gas system, without frequent adjustment. The system is designed to operate on a 115-v a-c power supply, and requires total power of about 1 kw. The present instrument is frequency-sensitive. This prevents its use as a portable unit which would be supplied by a small gasoline-driven generator.

Performance

The contractor tested the model unit for two months before delivery. Tests on tap water indicated that the per cent DO saturation was consistently within 1.5 per cent of the saturation value determined by the Winkler method (3). The 90-per cent response time was found to be about 3.5 min due to the increased efficiency of aspiration and gas separation as compared with the prototype.

Preliminary tests on the aeration tank mixed liquor at the Michigan City, Ind., activated sludge plant indicated that solids up to 4,000 mg/l would not clog the system, but continuous sampling caused the pump motor to overheat. Tests conducted on the contents of the final settling tanks at this same plant indicated the same precision as was found with tap water. At low DO there was a tendency toward frothing in the cyclone separator. Since this condition was more pronounced on Mondays, it was believed to be caused by high detergent concentrations.

Further tests were made by the purchaser on an algae-laden fish pond and on the Ohio River below the main sewage outfalls of Cincinnati. Mechanical functioning was satisfactory. Consistently high DO results brought about the discovery of an air leak on the suction side of the pump. Gas brought into the system through this leak was thought to be the major cause of the discrepancies.

The instrument was then tested on tap water for three days with the water temperature varying from 8.8 to

TABLE I.—Comparison of Oxygen Saturation by Winkler Procedure with DO Analyzer Using Tap Water *

Experiment Number	Trial	DO† (mg/l)	Water Temp. (°C)	Per Cent Saturation, Winkler	Per Cent Saturation, DO Analyzer	Difference
I	1	12.09	12.3	112.5	117.0	4.5
	2	12.09	12.3	112.5	117.0	4.5
	3	12.12	12.3	113.0	117.0	4.0
II	1	10.79	15.8	108.0	112.5	4.5
	2	10.83	15.8	108.5	112.5	4.0
	3	10.83	15.8	108.5	112.5	4.0
III	1	9.06	20.8	100.5	101.0	0.5
	2	9.01	20.8	100.0	101.0	1.0
	3	9.06	20.8	100.5	101.0	0.5
IV	1	7.82	29.7	102.0	100.0	−2.0
	2	7.82	29.7	102.0	100.0	−2.0
	3	7.81	29.7	102.0	100.0	−2.0
V	1	0.06	23.8	0.6	0	−0.6
	2	0.03	23.9	0.4	0	−0.4
	3	0.03	24.0	0.4	0	−0.4
VI	1	6.90	8.8	59.0	58.5	−0.5
	2	6.86	8.9	59.0	58.5	−0.5
	3	6.81	9.0	58.5	58.5	0
VII	1	4.67	22.8	53.5	49.5	−4.0
	2	4.67	22.8	53.5	49.5	−4.0
	3	4.67	22.8	53.5	49.5	−4.0

* Cincinnati, Ohio.
† Using Winkler method.

TABLE II.—Comparison of Oxygen Saturation by Winkler Procedure with DO Analyzer Using Raw Ohio River Water *

Experiment Number	Trial	DO† (mg/l)	Water Temp. (°C)	Per Cent Saturation, Winkler	Per Cent Saturation, DO Analyzer	Difference
I	1	10.35	15.8	103.5	108.0	4.5
	2	10.40	15.8	104.0	108.0	4.0
	3	10.38	15.8	104.0	108.0	4.0
II	1	10.48	15.6	104.5	109.5	5.0
	2	10.44	15.6	104.0	109.5	5.5
	3	10.53	15.6	105.0	109.5	4.5
III	1	10.36	15.7	103.5	106.0	2.5
	2	10.36	15.7	103.5	106.0	2.5
	3	10.36	15.7	103.5	106.0	2.5
IV	1	10.46	15.6	104.0	107.0	3.0
	2	10.46	15.6	104.0	107.0	3.0
	3	10.44	15.6	104.0	107.0	3.0
V	1	10.68	15.7	107.0	111.0	4.0
	2	10.68	15.7	107.0	111.0	4.0
	3	10.68	15.7	107.0	111.0	4.0
VI	1	10.67	15.5	106.0	109.0	3.0
	2	10.70	15.5	106.5	109.0	2.5
	3	10.71	15.5	106.5	109.0	2.5
VII	1	9.95	15.4	99.0	104.0	5.0
	2	9.92	15.4	98.5	104.0	5.5
	3	9.98	15.4	99.5	104.0	4.5

* At California Water Filtration Plant, Cincinnati, Ohio.
† Using Winkler method.

29.7°C and the DO from 0 to 117 per cent of saturation (Table I). The unit was transferred to a water filtration plant where it was in operation for nine days without incident. Since it was not feasible to connect the analyzer directly to the raw water line, the water was pumped to a surge tank, from which it was pumped to the analyzer. Samples for the Winkler determination were siphoned from the surge tank near the instrument intake line. It was realized that absolute correspondence of instrumental feed with samples drawn for the Winkler analysis is not guaranteed by this procedure. Data for these tests are also shown in Table II. In this study it was anticipated that DO samples for Winkler determinations could be taken from the instrumental feed line.

Experimental stabilization ponds in southern Ohio were used to test the instrument under conditions of high solids and fluctuating DO levels. During nine days of operation the aspirator was clogged once by a small stone which passed the intake screen on the end of the suction hose. The "fail safe" mechanism was actuated once when exhaustion of the gas supply caused the nitrogen pressure to drop below 3 psi. Frothing did not appear to be a problem in this installation.

Because of the shallow depth of the pond and the DO stratification, a sampling valve was placed between the pump and the instrument in order to draw off a representative sample for the Winkler test. Table III includes these data. It was noted that the high algal population and/or high organic

content of the water interfered with the end point in the Winkler determination. Although such interference was noted, rather close agreement with the instrument values was obtained.

During a final laboratory check of the instrument a determination was made of the water temperature increase through the pump and instrument. The water drawn from the supply line had a temperature of 3.4°C on the suction side of the pump. The temperature immediately after the outlet orifice was 4.8°C. This increase of 1.4°C accounted for a 6 per cent increase in the per cent saturation as determined by the Winkler method applied to samples taken from the intake line.

Limitations

As the result of the testing program certain limitations or needs for improvement were noted. It will be necessary to equip the intake line with a screen to prevent entrance of particles large enough to clog the small aperture in the aspirator, as the pump motor is likely to burn out if the aspirator becomes clogged. The need for inclusion of an overload shut-off to prevent damage is indicated.

Damage due to pump overheating in situations where high solids are encountered such as activated sludge mixed liquors can be overcome by the use of a larger pump motor.

The practical limit on the pump suction head is about 25 ft. In some situations there may be separation of the gas and water. However, the gas would be drawn along with the water and part of it might find its way back into solution again in the pump. In the event not all of the gas is redissolved the gas would enter the aspirator and an oxygen equilibrium would be obtained. The greatest lift encountered in the test studies was about 10 ft.

During continuous operation the pump bypass valve had a tendency to clog or close due to vibrations which required that the valve be reset at 24- to 48-hr intervals. This tendency has been overcome by replacement with a spring-loaded relief valve.

When the unit is moved it is neces-

TABLE III.—Comparison of Oxygen Saturation by Winkler Procedure with DO Analyzer Using Waste from Stabilization Ponds*

Experiment Number	Trial	DO† (mg/l)	Water Temp. (°C)	Per Cent Saturation, Winkler	Per Cent Saturation, DO Analyzer	Difference
I	1	0.66	13.0	6.2	8.0	1.8
	2	0.66	13.0	6.2	8.0	1.8
	3	0.82	13.0	7.7	8.0	0.3
II	1	0	13.0	0	1.0	1.0
	2	0	13.0	0	1.0	1.0
	3	0	13.0	0	1.0	1.0
III	1	3.50	20.3	38.5	39.0	0.5
	2	3.33	20.3	36.5	39.0	2.5
	3	3.31	20.3	36.5	39.0	2.5
IV	1	2.37	14.2	23.0	28.0	5.0
	2	2.73	14.3	26.5	32.0	5.5
	3	2.51	14.3	24.5	32.0	7.5
V	1	1.97	11.4	18.0	20.0	2.0
	2	1.86	11.4	17.0	20.0	3.0
	3	1.45	11.4	13.0	17.5	4.5

* Lebanon State Farm, Lebanon, Ohio.
† Using Winkler method.

sary to re-secure the water line connections since small gas leaks affect the accuracy of the instrument. In permanent installations this difficulty is not expected to develop; however, periodic pressure tests are advisable.

The difficulties encountered with frothing have been minimized by redesign of the aspirator entrance and by relocation of the "fail safe" contacts.

Since the instrument described herein requires a constant frequency a-c power supply, it cannot be used on a boat or in other locations remote from a frequency-stable power supply. It is intended, therefore, to convert the analyzer and recorder circuits to d-c, which can be supplied by portable generating units. To enhance the attractiveness of the equipment for portable use, the analyzer, aspirator, and separator are being redesigned to reduce the size and weight.

When the temperature of the water to be analyzed varies from the water temperature for which the instrument is calibrated, an error is introduced into the analysis (1). This error is minimized, however, by a compensating error due to the effect of water vapor on the analyzing component of the instrument. The error due to water temperature increase through the instrument has been reduced by redesign of the pump unit.

Summary

An instrument for the continuous analysis of dissolved oxygen in water has been developed based on theories established in earlier work (1) (2). The instrument performed reasonably well in laboratory and field tests and under a variety of water conditions and DO levels. Accuracy was mostly within ± 5 per cent of saturation as compared to the Winkler test. Difficulties encountered with clogging, frothing, and leaks were few and service checks were generally not required at less than 24-hr intervals. Although the instrument can be set up at field installations, power requirements preclude its use as a mobile operating unit. Future models will include design changes to overcome these difficulties.

Acknowledgment

The authors acknowledge with gratitude the assistance rendered by J. B. Gifford of the Michigan City, Indiana, Sewage Treatment Plant; G. E. Perry of the State Fish Hatchery, Newtown, Ohio; J. D. Enright of the California Water Filtration Plant, Cincinnati, Ohio; and the management of the Western Hills Yacht Club, Cincinnati, Ohio.

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THE DESIGN AND COST OF STABILIZATION PONDS IN THE MIDWEST

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Stabilization ponds are commanding increased attention as a means of sewage treatment for many small and some medium-size communities. The 1957 "Inventory of Municipal and Industrial Waste Facilities" (1) (2) discloses that there are 430 municipal sewage stabilization ponds in the country today. This represents about 10 per cent of all secondary sewage treatment facilities. The location of these stabilization ponds by major drainage basins is shown in Table I.

Approximately 20 per cent of the 1,038 projects participating in the Public Health Service's construction grant program on June 30, 1958, include the construction of sewage stabilization ponds. This paper reports on a study of engineering design, construction costs, and provisions made for operation and maintenance of 31 raw sewage stabilization ponds selected at random from seven midwestern states with widely varying geographical and climatological conditions. Over half of all stabilization pond projects receiving federal financial assistance under the construction grants program are located in these states. The locations of the projects studied are shown in Table II.

The raw sewage stabilization ponds described in this paper serve small communities of relatively stable population having little or no industrial wastes. Fifteen of the projects are being built in communities that were formerly unsewered.

TABLE I.—Sewage Stabilization Ponds in the United States

Major Drainage Basin	No.	Pop. Served
Northeast	1	400
North Atlantic	1	900
Southeast	9	13,300
Tennessee River	1	570
Ohio River	1	900
Lake Erie	—	—
Upper Mississippi	38	39,975
Western Great Lakes	1	320
Missouri River	123	125,482
Southwest-Lower Miss.	55	121,176
Colorado River	38	68,632
Western Gulf	91	163,400
Pacific Northwest	11	10,535
California	45	191,646
Great Basin	15	22,705
Total	430	759,941

Design Basis

Preliminary studies by consulting engineers were usually confined to estimates of present and future populations. Flow measurements were made in a few instances; but, more often, assumed per capita flows were used. In nearly one-half of the engineering reports examined no mention was made of sewage flow or strength.

Basic design data for all projects included in this study are summarized in Table III.

Number and Types of Cells

The number of stabilization ponds with one, two, three, and four cells is shown in Table IV. There are three

TABLE II.—Location of Stabilization Pond Projects Studied

State	No.	Pop. Served
Iowa	1	600
Kansas	2	3,500
Minnesota	3	9,300
Missouri	8	11,000
Nebraska	4	1,200
North Dakota	7	12,300
South Dakota	6	5,300
Total	31	43,200

distinct types of two-cell installations. The most common type employs one inlet, an interconnecting pipe, and an outlet pipe. This arrangement permits series operation only. A second type provides an inlet pipe to each cell, an interconnecting pipe, and one overflow pipe. This arrangement permits series operation, operation of only one cell, and a basically parallel operation with sewage flowing to both cells simultaneously. A third type employs an inlet pipe to each cell, an interconnecting pipe, and an outlet pipe from each cell. With this arrangement, single-cell, series, or true parallel operation can be obtained.

The number of cells in each stabilization pond and their arrangement were found to be markedly influenced by state design recommendations which vary appreciably. For example, North Dakota recommends that multiple cells be used for further treatment when the effluent discharges continuously to a stream. Minnesota specifies that primary and secondary

TABLE III.—Stabilization Pond Design Data

Item	Range	Avg	Median
Design pop. equivalent	300–13,700	2,080	1,030
Surface area (acres)	1.75–157	17.7	10.0
Ratio of total land purchased to water surface area	1.1–7.6	2.2	1.9
Water depth (ft)	3–5	4.0	4.0
Freeboard (ft)	2–5	3.2	3.0
Top dike width (ft)	8–20	10.0	10.0
Inside slope	2.5–7:1	4.2:1	4:1
Outside slope	2–4:1	3.1:1	3:1
Distance between pond and nearest house (ft)	400–2,640	1,240	1,150

TABLE IV.—Types of Sewage Stabilization Ponds

No. of Cells	No. of Projects
1	14
2	14
3	2
4	1

ponds must be provided in all cases. The Missouri design guide does not specify when multiple cells are necessary, and all of the eight Missouri projects examined in this study are single-cell installations.

Surface Loadings

Design surface loadings vary considerably from state to state and from project to project within individual states. Variations in state requirements concerning surface loadings are illustrated by the following examples. Minnesota sets the maximum BOD loading of the primary pond at 0.46 lb/1,000 sq ft (20 lb/acre) and requires the secondary pond to be one-third the area of the primary unit. North Dakota sets the maximum BOD loading as either 0.46 lb/1,000 sq ft or 100 people/acre, but the total area of two cells can be used in computing the loading. Missouri has recently increased the allowable surface loadings from 100 to 200 population equivalents per acre. Variations within individual states are attributed to several factors among which are increased knowledge of pond design, latitude, climatological conditions, and the practice of some communities to build one cell to handle present loads with the intention of adding another cell at a later date to take care of the total design loads.

Depth

All 31 stabilization ponds were designed for uniform depths varying from 3 to 5 ft. It is interesting to note that two-thirds of the projects utilize maximum design depths of an even 3 or 5 ft rather than depths between these two limits. Design data do not

show any definite relationship between depth and surface area, or between depth and geographical location.

Dike and Bottom Construction

Nearly all of the stabilization pond construction specifications call for the area under the dikes to be thoroughly cleared, stripped of vegetation, and scarified. It was deemed necessary to require the placement of selected borrow in dikes in about 50 per cent of the installations. This borrow will be placed as a cutoff wall, dike core, dike facing, or will be used to construct the entire dike in a few instances. In many cases specifications allow considerable latitude as to the quality of the borrow. General phrases such as "material shall be selected for impermeability" and "material with a high plastic content" are frequently used.

Specifications concerning type and degree of compaction for dike material vary appreciably. Nearly all specifications prescribe a maximum "lift" which can be placed before compacting. This was usually 6 in., but in some cases an 8- to 10-in. depth was allowed. The simplest method of compaction specified was to route earthmoving equipment over the fill area. Another commonly used method prescribed rolling with a sheepsfoot roller of specified weight until the feet no longer penetrated the ground. The standard American Association of State Highway Officials density test was specified in five cases.

Special measures were required in about one-third of the installations for the sealing of pond bottoms. Betonite was specified for this purpose in three installations. Other measures included scarification and recompaction of cut areas and blankets of selected borrow.

Inlet Devices

Pond designs call for inlet devices of either the horizontal or vertical discharge type. The most common type utilizes a horizontal discharge from a pipe resting on a concrete "splash pad" at the bottom of the pond. Refinements to this basic scheme include a block with a divider and an elbow and tee arrangement to disperse the flow horizontally in two directions. Eight installations utilize an upward vertical discharge influent line. The end of the pipes will be placed from 6 in. to 1 ft above the bottom of the pond. One design calls for a plate to be placed above the discharge end of the pipe to increase flow diffusion. Four designs of both horizontal and vertical discharge types require a dished-out area 1 to 2 ft deep at the point of discharge. The horizontal location of the inlet is, in all cases, located near the center of approximately square ponds and near the one-third point on long rectangular shapes. Where secondary ponds are used in series with a primary pond, the influent to the secondary is located near the edge of the dike separating the two ponds.

Overflow Structures

Many types of devices for controling the depth of the stabilization ponds are used. The simplest of these is an overflow pipe through the dike at the high water level. A type used extensively in North Dakota consists of a pipe located at the bottom of the pond with a gate valve located within a manhole in the dike to control the flow. This is needed to prevent freezing during winter operations. An overflow structure commonly used in Missouri includes two pipes located at maximum and minimum depths which slope upward from beneath the water surface to a manhole in the dike. The flow from the lower pipe is controlled by a valve or sluice gate. This arrangement satisfies two Missouri recommendations concerning outlet structures in that the pond can be operated

at depths of from 3 to 5 ft and the effluent is removed from a point approximately 6 in. below the surface. Probably the most versatile outlet device, variations of which are used in seven installations, consists of a manhole divided by a wall containing stop planks. With the influent line to this manhole located at the bottom of the pond, this arrangement provides a means of regulating the pond depth between complete drainage and maximum design depth.

There was a wide variation in choice of effluent withdrawal elevations. Ten installations provided for the removal of effluent from the bottom only. Thirteen provide a means of withdrawal at a point 6 in. to 1 ft below the water surface. The remaining seven will withdraw effluent from the water surface. Four of the latter type have either a skirt or screening bars around the influent end of the overflow to minimize the amount of floating material removed.

Flow Measurement, Fencing, and Seeding

Flow measurement devices consisting of rectangular weirs, V-notch weirs, Parshall flumes, Venturi meters, or pump timers will be employed in 14 of the 31 projects.

Fencing was included in the contract in nearly every project. Barbed wire and woven wire topped by barbed wire were used approximately the same number of times.

Seeding of dikes and areas disturbed by construction was made part of the pond contract in 75 per cent of the projects. The municipalities assumed this responsibility in the remaining instances. A great many different grasses were specified, but those which have a short root system (to prevent leaks in the dike) and provide heavy cover (to prevent surface erosion) predominated.

Surface Runoff

Most of the installations were designed to prevent surface runoff from entering the pond. In approximately one-third of the installations it was necessary to construct intercepting ditches. In the remaining projects the dikes surrounded the entire pond making further runoff control measures unnecessary.

Construction Costs

Cost data collected and analyzed include the contract cost of excavation and earth placement, all piping within the periphery of the dikes, inlet and outlet structures, fencing, and seeding. Costs of pumping stations and interceptor and outfall sewers were excluded because of their widely varying magnitude.

Costs have been related to surface areas rather than to design populations because of the variation in prescribed surface loadings. The resulting cost curve for Missouri projects shows a wide variation in unit costs for any total stabilization pond surface area. These differences in costs cannot be attributed to the number of cells comprising the total surface area or types of control structures, because all ponds are single-celled and of similar design in other respects. The two factors primarily responsible for differences in costs are the unit cost of excavation and the amount of excavation necessary

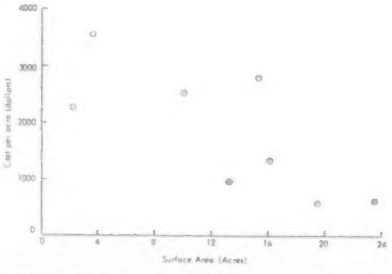

FIGURE 1.—Stabilization pond contract costs in Missouri.

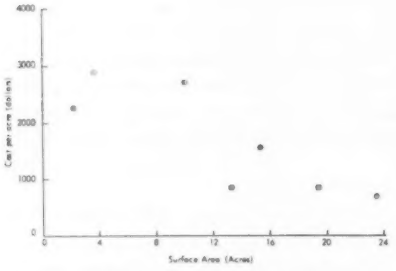

FIGURE 2.—Stabilization pond costs in Missouri based on actual excavation quantities and a statewide average cost of excavation.

to provide a given surface area. The importance of these two factors is illustrated in Figures 1, 2, and 3. Figure 1 shows the arrangement of unadjusted contract cost data and surface areas. Unit costs for Figure 2 were calculated by using the actual cost of appurtenances and the actual amount of excavation, but the statewide average cost of excavation. Cost data plotted in Figure 3 include the actual cost of appurtenances, the average cost of excavation, and a calculated quantity of excavation. This calculated quantity is twice the theoretical amount of excavation required to build a square, one-cell stabilization pond on a level surface with balanced excavation and embankment. Average berm widths, dike slopes, and water depths were used in this theoretical pond. The theoretical excavation was multiplied by a factor of two to account for the fact that the actual average excavation for the Missouri projects was approximately twice the theoretical requirement. In one case, the actual excavation was four times the theoretical requirement because of adverse topographical conditions. Conversely, in some projects where depressions could be utilized the actual excavation was less than that theoretically required.

The unit cost for excavation of 29¢/cu yd used in Figures 2 and 3 was determined by averaging the excavation cost of 16 projects constructed in Missouri during the last year and a half. These costs ranged from 16.5 to 63¢/cu yd.

The design and cost characteristics of stabilization ponds constructed in North Dakota, South Dakota, and Nebraska are quite similar. For this reason, they were studied as a group. As shown in Figure 4, there is a rather good correlation between the unad-

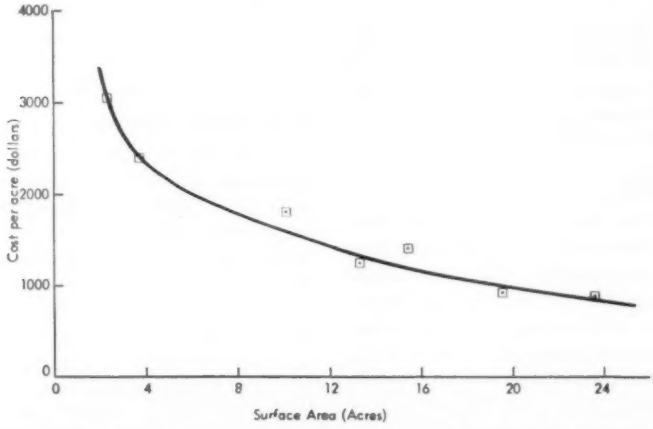

FIGURE 3.—Stabilization pond costs in Missouri based on a statewide average cost of excavation and adjusted excavation quantities.

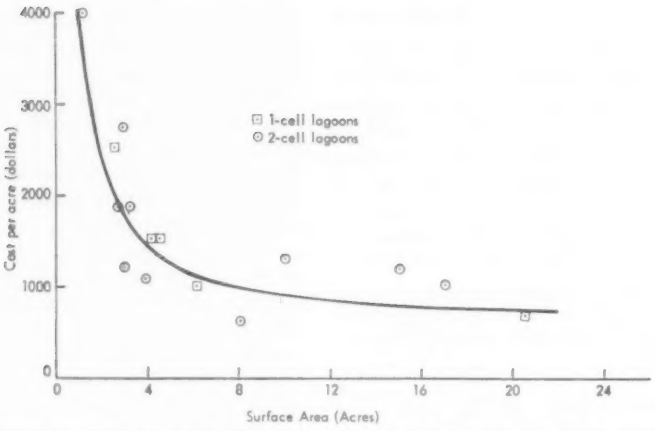

FIGURE 4.—Stabilization pond contract costs in Nebraska and the Dakotas.

justed contract cost data for these projects. When adjusted as for Missouri, there was little improvement. This is to be expected, however, for there was less variation in unit cost of excavation and less variation in the quantity of excavation necessary to provide a given surface area. It is interesting to note that there is little difference in costs between one- and two-cell stabilization ponds.

The construction details and costs of the one project in Iowa, two in Kansas, and three in Minnesota are quite dissimilar from those in the other states. Because of this, the cost data were excluded from consideration with the other projects. The limited number of projects in this group precluded a separate cost analysis.

Other Costs

The total first cost of projects analyzed in this study was approximately 20 per cent greater than the actual contract cost. Included in this 20 per cent were engineering, legal, administrative, and contingency costs. Land costs were not included in any of the cost figures. The "per acre" cost of land varied over a wide range and was not necessarily proportional to amount of land purchased, or any other discernible factor.

Operation and Maintenance Costs

Operation and maintenance cost estimates were difficult to analyze since a lump sum was usually estimated for ponds, sewers, and pumping stations. However, for the few installations for which data are available a total of from $250 to $500 per year was allowed for ponds under 10 acres in area. Activities provided for in this allowance include mowing and weed control on dikes, general repairs of fences, dikes, etc., and inspections.

Discussion

Preliminary Planning

As would be expected in planning treatment facilities of this type, less care was taken in estimating future population, flow, and strength than that found to be given in planning conventional secondary plants (3). Other aspects of preliminary planning peculiar to stabilization pond design such as studies of prevailing wind direction, evaporation-precipitation relationship, etc., were not usually undertaken for individual installations, though these factors may have been

considered on an area-wide basis. In spite of certain factors of safety inherent in sewage stabilization ponds as compared with conventional secondary treatment plants, improved design could well result from more thorough engineering studies.

Soil Compaction

Specifications concerning the degree of soil compaction in the construction of stabilization ponds were generally quite liberal. Newer methods for determining compaction and stability could well replace less reliable methods, especially when the consequences of dike failure or excessive leakage could be both costly and hazardous to health.

Seepage

Apparently there are some basic questions concerning stabilization pond seepage which remain unanswered. These are:

1. Is seepage a legitimate and desirable means of disposing of pond effluent?
2. If seepage is sometimes a desirable means of disposal, to what extent and under what conditions should it be permitted?
3. If seepage is undesirable, what methods and materials should be used to prevent it?

This study disclosed that there is a difference of opinion in regard to Question 1. Missouri states in its design guide: "Percolation rates of the finished floor established in accordance with latest PHS recommendations must not exceed 0.25 inch per day. Sealing will be required when this rate is exceeded." North Dakota states: "Soil formations should be relatively tight to avoid undue liquid losses through percolation."

The fact that some design engineers made soil borings indicates concern over Questions 2 and 3. In at least 2 of the 31 projects there were reports of excessive seepage which may require special sealing.

With respect to Question 3, the engineer is confronted with the problem of finding a material which will adequately seal the pond and yet be inexpensive enough for this type of project to maintain its low-cost feature. Bentonite clay was used for this purpose in three installations. In two cases applications of 1 lb/sq ft were specified. Bids of 20 and 50¢/sq yd were accepted for furnishing and placing this material. In the other installation the clay was applied at a rate of 0.5 lb/sq yd for 18¢/sq yd. There was one other project for which costs were available for special sealing material. In this project a 6-in. compacted layer of native clay was specified and the bid cost was 50¢/cu yd or 8⅓¢/ sq yd.

Construction Costs

Construction cost data do not display the expected relationship between unit costs and populations served when plotted on a per capita basis, and it is felt that a comparison of costs on an acreage basis is more desirable. Accordingly, adjusted cost data, based on average unit costs of excavation and calculated quantities of excavation were used in this study in order to establish a basis for comparison. The idea of using average excavation costs for certain areas is accepted in other construction fields; however, the problem of determining the excavation required to provide a unit of surface area is difficult to generalize. In most cases the total cost of excavation ranged from 40 to 70 per cent of the total contract cost, with an average of about 56 per cent. Therefore, over one-half of the total adjusted cost was developed on a quasi-theoretical basis.

The cost data presented in Figure 4 can be readily translated into cost per unit of flow or per capita served through the application of known or estimated design factors for daily per

capita flow and population served per acre of stabilization pond. Comparison of pond costs developed in this manner with costs of other types of treatment must include consideration of relative land, operation, and maintenance requirements and the longer outfall sewers usually required for stabilization ponds because of their greater distance from the community served.

Summary and Conclusions

Engineering investigations preliminary to the design of raw sewage stabilization ponds were very limited in scope.

State design recommendations have a marked effect on the loading, number, and arrangement of cells. There is considerable variation in these recommendations within similar geographical areas.

Several basic questions relative to seepage from stabilization ponds remain unanswered. Differences in state standards and liberally written engineering specifications as to dike and bottom compaction and permeability illustrate the need for greater knowledge and guidance in this respect.

Construction cost data for stabilization ponds in three states disclosed a high degree of correlation when developed on the basis of cost per unit of surface area.

Construction cost data for similar projects in one state displayed little correlation when developed on the same basis. A technique was devised for delineating the cause of widely varying unit costs and for the reduction of such costs to a rational relationship.

References

1. "Inventory of Municipal and Industrial Wastes Facilities in the United States —1957." Publ. Health Service Publication No. 622.
2. Thoman, J. R., and Jenkins, K. H., "Statistical Summary of Sewage Works in the United States." Publ. Health Service Publication No. 609.
3. Howells, D. H., and Dubois, D. P., "Small Sewage Treatment Plant Design in the North-Central Region of the United States." THIS JOURNAL, **30**, 11, 1327 (Nov. 1958).

TREATMENT DESIGN MANUAL CORRECTIONS

Attention has been directed to two errors in the recently published FSIWA Manual of Practice No. 8 (ASCE Manual of Engineering Practice No. 36), "Sewage Treatment Plant Design."

1. On the bottom of page 168, under Type I, the dosing rates should read "between 10 and 30 mgad," rather than "between 10 and 30 mgd."
2. In the middle of page 156 in reference to Figure 8, on page 157 within Figure 8, at the top of page 157 in reference to Figure 9, and on page 158 within Figure 9, the relationship $R = \frac{Q'}{Q}$ is incorrect. The correct recirculation relationship is $R = \frac{Q' - Q}{Q}$.

Journal readers are urged to contact either sponsoring organization as soon as possible if other errors are noticed. This request is made with the expectation that an errata sheet can be prepared and included in all copies sold after its issuance. Such errata sheets would also be available on request to those already in possession of the Manual.

METABOLIC ENERGY BALANCES IN A TOTAL OXIDATION ACTIVATED SLUDGE SYSTEM *

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Total oxidation of the organic influent substrate in a waste treatment system was first proposed by Porges, Jasewicz, and Hoover (1) in 1953. They developed the theory of the substrate being removed and assimilated into new cells as Phase I, and the entire flora of the cells being self-oxidized (endogenous respiration) in what was called Phase II. It was claimed that in Phase I, 52 per cent of the substrate reappeared as new cells (activated sludge). This rate of new cell production agreed in general with other results reported by Placak and Ruchhoft (2), Helmers *et al.* (3), and Gellman and Heukelekian (4), in their studies of activated sludge mechanisms. In Phase II, Porges *et al.* (1) measured an endogenous rate of one per cent per hour, or a total time of 460 hr for 99 per cent endogenous oxidation of a unit-mass of newly created cells. In previous work there was an observed rate of 1.25 per cent per hour in a 15,000-gal dairy waste treatment pilot plant tank for a period of 58 hr of continuous aeration.

These data indicated that there should exist an equilibrium between the weight of new sludge created and the weight of sludge lost by self-oxidation. This suggests that there could result a system in which the entire influent was eventually oxidized, and thus there would be no sludge removal required.

To investigate this theory, small industrial waste and sanitary sewage treatment plants were constructed embodying these proposed principles. However, the lack of complete operating data and erratic quantities and qualities of influent limited the accumulation of usable data. It was suspected that these systems regularly discharged low concentrations of activated sludge and thus produced a pseudo-equilibrium. Symons and McKinney (5) showed that total oxidation of such flora was not possible and that a small amount of non-oxidizable polysaccharide material remained. Some theories were proposed that alternate feeding and starving of a culture produced atypical data.

The accurate evaluation of such an entire system could best be demonstrated by a continuous operation with a uniform concentration of influent having a known chemical composition, and with measurement of the system effluents (gaseous, liquid, and solid).

Equipment

The experimental system consisted of a series of six aeration tanks, a substrate dispenser, and a clarifier as shown in Figure 1. The influent was formed by adding 0.2 gpm of skim milk powder solution by means of a positive displacement pump (Sigmamotor), the strength of the solution being prepared so as to feed 1.65 lb of dry milk solids per 24 hr.

Skim milk powder (52-per cent lactose, 37-per cent casein, and 11-per cent ash) was used because of its uniformity in chemical composition, its

* Presented at the 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

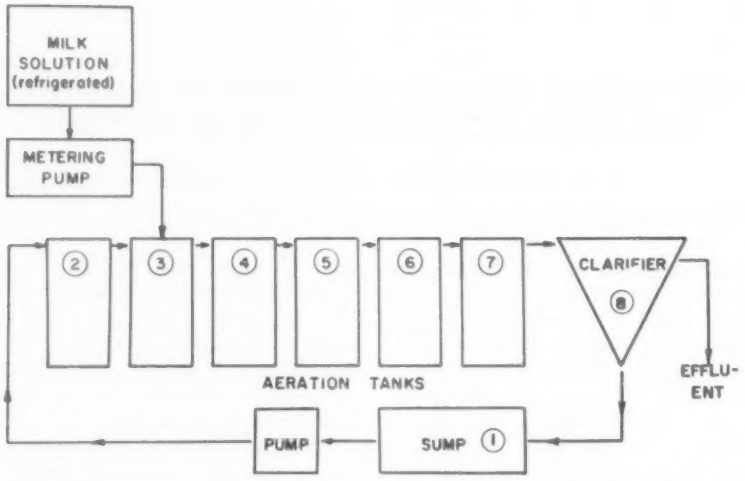

FIGURE 1.—Schematic flow diagram of total oxidation test apparatus using multiple-unit aeration.

economy in bulk and in cost, its easy solubility, its desirable C–N ratio, and most important its similarity in chemical components to those of sanitary sewage.

The clarifier and sludge withdrawal mechanism are shown in Figure 2. Overflow weir troughs at the top of the pyramidal unit removed the effluent at an average rate of 0.2 gpm. The settled sludge was removed to a sump through a bottom-connected draw-off pipe. The amount of sludge withdrawn was controlled by a timer-operated solenoid valve so that the sludge was returned from the sump to the aeration system at a rate of 0.8 gpm. Thus the rate of flow of the mixed liquor was 1.0 gpm.

Each of the six aeration units was provided with a vertical partition which created essentially a U-tube unit. The partition was used to minimize short circuiting. As shown in Figure 3, each tank also had an immersed bell jar which captured a known fraction of the respired gas for carbon dioxide analysis.

Operation and Analysis

The system originally inoculated with a mixture of activated sludge from a domestic sewage treatment plant and a water extraction of top soil, was in continuous operation for approximately six months prior to the collection of any data reported here.

Essentially the system had a detention time of seven and one-half hours: one hour of sludge aeration prior to substrate addition, five hours of aeration following substrate addition, and one and one-half hours of clarification and sludge return. The system design also provided for changing the point of influent addition to any of the six aeration tanks, as desired; however, during the period of this report the influent was added to the second aeration tank.

Preceding the series of observations the following average characteristics of the system were determined:

Item	Value
pH	7.2
Temperature	75°F
Oxygen supply	≧2.0 ppm

Also, it was found that the removal of the skim milk solids from solution as measured by the COD and lactose tests was so rapid that none of the components could be detected in the substrate after 30 min, which was the shortest sampling time available.

Observations

Oxygen Usage

The fractions of respired gas removed from each of the tanks were analyzed to determine the amount of carbon dioxide respired. Porges *et al.* (6) have shown by extensive tests with dairy wastes and municipal activated sludge that the oxygen-used and carbon dioxide-expelled ratio is 1:1 by weight, therefore it was possible to obtain the oxygen usage profile shown in Figure 4. Attention is directed to the immediately high value following the addition of the substrate which indicates the energy expended to stabilize the organic substrate. There was an excessive production of carbon dioxide

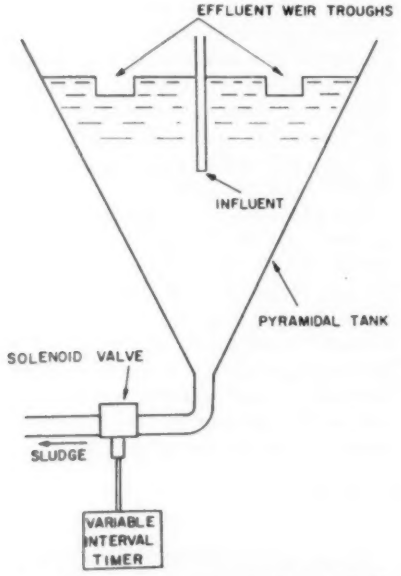

FIGURE 2.—Schematic details of clarifier shown in cross-section.

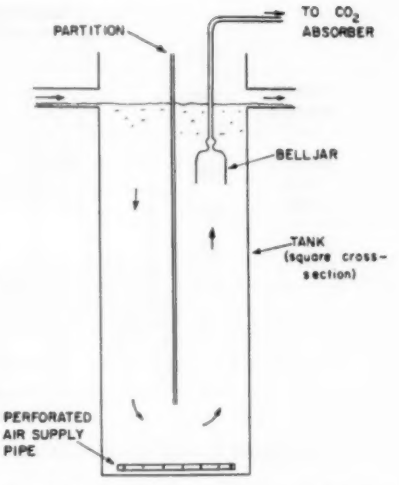

FIGURE 3.—Schematic details of aeration tank shown in cross-section.

in the first aeration unit following the return of the sludge to the aerated phase. It is believed that this was due to the system metabolism which continued to operate (with the aid of the residual dissolved oxygen) while the sludge was in the clarifier and sump. This carbon dioxide production also could have been caused by anaerobic action but continuously high oxidation-reduction potentials and no appearance of reduced nitrogen compounds in the unaerated portion of the system disallowed this.

Nitrogen Balance

Nitrogen assays were made on the effluent, collected over a 24-hr period, and on the activated sludge. Within the limits of nitrogen analysis, all of the influent nitrogen was found in the effluent; the percentage of nitrogen in the cellular material did not change; and no evidence could be found of ammonia being present in the respired gas. The highly aerobic state of the system was indicated by the lack of any appreciable amount of either ammonia or nitrite nitrogen at any place in

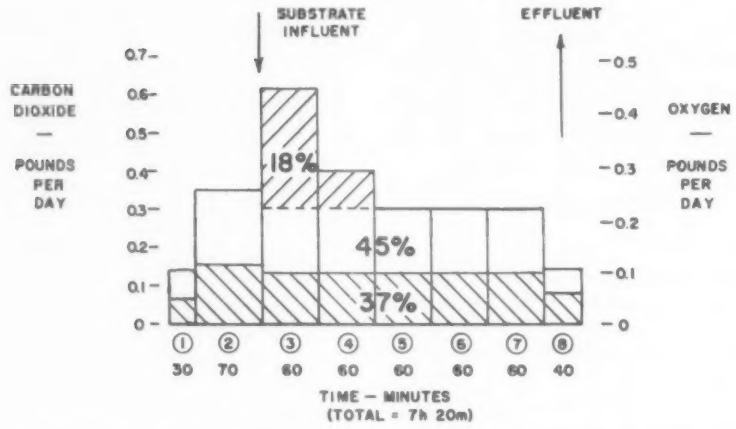

FIGURE 4.—Carbon dioxide and oxygen profile for total oxidation tests.

the system including the sedimentation unit and sump.

Solids Balance

The weight of suspended solids (in the system and lost in the effluent) was determined by the membrane filter method described by Engelbrecht and McKinney (7). Effluent solids determinations were made on a composite sample collected over a 24-hr period by means of a Sigmamotor pump. The first solids balance was maintained for a period of 44 days, during which the total weight of solids in the aeration system remained constant but there was a discharge of 0.122 lb of sludge in the effluent each day. The second solids balance was attempted with no discharge of sludge for a period of 80 days, but this resulted in a uniform increase of solids in the system of 0.122 lb/day.

Discussion

Activity Classification

Respired carbon dioxide as shown in Figure 4 is in relation to the time cycle intervals of the purification system. As shown by the alternate ordinate parameter, this also represents oxygen utilized in the system cycle. The portion of total carbon dioxide identified with the clarifier and sump was actually measured in the first aeration unit of the series. The respiration rate of the starved sludge (caused by suspension of influent for 36 hr) is shown also in Figure 4 as the lower shaded area. Inspection of these data indicates three types of activity which utilized oxygen: primary oxidation, assimilation into new sludge, and endogenous respiration. Primary oxidation is shown in the upper shaded area, new cell formation in the unshaded center portion, and endogenous respiration in the lower shaded area.

The purification of substrate utilized 18 per cent of the total oxygen required, which value agrees well with the data reported by Wuhrmann (8) of 15 to 18 per cent when there is no nitrogen deficiency. The value of 18 per cent also agrees with the probable equation of the oxidation of 37.5 per cent of the influent lactose for energy needed to purify the substrate:

$$3\ CH_2O + 3\ O_2 \rightarrow 3\ CO_2 + 3\ H_2O \quad (1)$$

As was demonstrated by Porges *et al.* (9) this purification effects an immediate storage in the sludge of the

remaining substrate material as glycogen. They found that a maximum glycogen content equal to 19 per cent of the sludge weight was possible and that this storage reduced the nitrogen content of the sludge to 7.5 per cent. The system being reported had an 8.5 per cent nitrogen content in its sludge in contrast to a theoretical maximum value of 12.4 per cent, and there was a sufficiency of nitrogen available. The upper portion of the uniform oxygen-use graph area (unshaded portion of Figure 4) represents a steady conversion of glycogen to new sludge. Absence of influent substrate after 30 min time also supports this theory.

Theoretical Comparisons

Attempts to interpret the carbon dioxide respiration in the classical form originally proposed by Porges *et al.* (1) were not successful. They reported the formation of two molecules of activated sludge having the formula $C_5H_7NO_2$ (this did not represent an actual compound; it merely gives the proportion of the oxidizable elements to oxygen). Symons and McKinney (5) reported a variety of formulas for the sludge molecule depending on the nitrogen availability, but with a common ratio of $C_{1.0}:H_{1.7}:O_{0.6}$ per nitrogen atom. Thus, a number of possibilities exist to explain the creation of new activated sludge. However, it can be proposed in view of the carbon dioxide respired in new sludge formation (total carbon dioxide less carbon dioxide from the purification and endogenous reactions) that a portion of the lactose stored as glycogen is utilized as an energy source, only.

Purification Energy:—

$$3\ CH_2O + 3\ O_2 \rightarrow 3\ H_2O + 3\ CO_2 \quad (1)$$

Assimilation Energy:—

$$3\ CH_2O + 3\ O_2 \rightarrow 3\ H_2O + 3\ CO_2 \quad (2)$$

New Sludge Formation:—

$$C_8H_{12}O_3N_2 + 3\ O_2 \rightarrow C_5H_7O_2N + H_2O + NH_3 + 3\,CO_2 \quad (3a)$$

$$2\ CH_2O + 0.4\ NH_3 \rightarrow 0.4\ C_5H_7O_2N + 1.2\ H_2O \quad (3b)$$

Endogenous Oxidation:—

$$C_5H_7O_2N + 5\ O_2 \rightarrow 5\ CO_2 + NH_3 + 2\ H_2O \quad (4)$$

These formulations would then allow the existence of an 8.4-per cent N sludge instead of the 12.4-per cent N value required by molecular formula because of its glycogen storage. It would also predicate the release of 0.6 of a mole of ammonia into the system which would then be oxidized to nitrate ion. This nitrate ion component, being part of the effluent substrate, would be evaluated along with the nitrate from endogenous activity and thus appear in the nitrogen balance.

Carbon and Nitrogen Balance

The carbon balance of the system mechanism as proposed is detailed in Figure 5, and Figure 6 shows in a similar manner the utilization of the nitrogen throughout the metabolic stages.

Cell Formation

To evaluate the sludge produced and oxidized in this system, attention is directed to the two sludge formation equations (3a and 3b) which would indicate the creation of 0.515 lb/day of new sludge instead of the value of 0.75 lb/day proposed by Porges *et al.* (9), from the same initial constituents (0.59 lb casein and 0.83 lb lactose). When the system was operating at an internal solids balance there was an effluent discharge of 50 mg/l of activated sludge, equivalent to 0.12 lb/day. The effluent solids discharge was eliminated with the result of a daily increase in the total system weight of activated sludge equal to 0.12 lb/day. This would indicate that 23 per cent of the sludge is non-oxidiza-

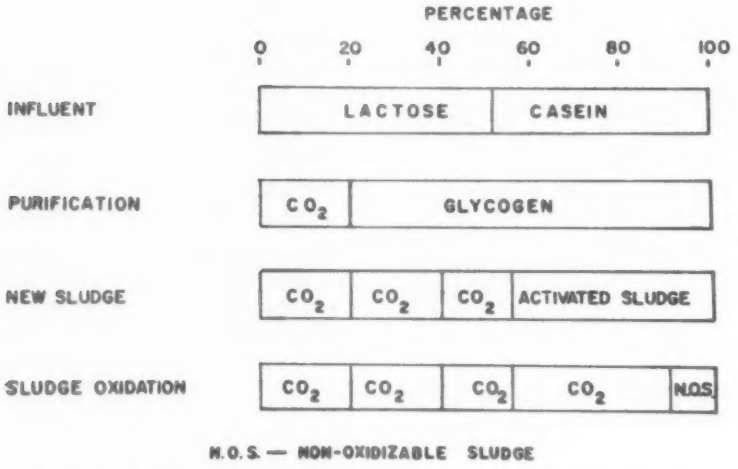

FIGURE 5.—Proposed carbon metabolism of a total oxidation system.

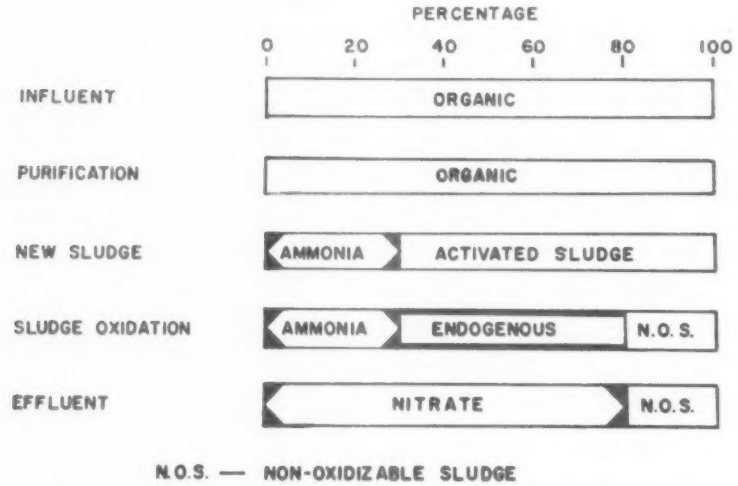

FIGURE 6.—Proposed nitrogen metabolism of a total oxidation system.

ble (polysaccharide material). Table I lists the sludge weights and the weights of carbon dioxide observed together with the theoretical values.

BOD Removal

The effluent with the sludge discharge of 50 mg/l was analyzed for BOD and found to average 8 to 10 mg/l. When its velocity constant k was determined by the moments method of Moore, Thomas, and Snow (10), the value was found to average 0.05, which would yield an ultimate oxygen demand L of 20 mg/l. Earlier work in studies using skim milk solutions and using the moments method yielded a value for k for the influent of 0.27. The influent 5-day BOD studied here was 600 mg/l, which was equivalent to

TABLE I.—Observed Weights of Sludge and Carbon Dioxide from Operation of Total Oxidation System*

Metabolic Phase	Eq. No.	Carbon Dioxide (lb/24 hr)		Activated Sludge (lb/24 hr)
		Theory	Measured	
Purification				
(3 CH_2O)	1	0.46	0.40	0.00
Assimilation:				
(a) (3 CH_2O)	2	0.46	—	0.00
(b) ($C_5H_{12}O_2N$)	3a	0.43	0.90	+0.36
(c) (2 CH_2O)	3b	0.00	—	+0.16
Endogenous (77% of new sludge formed)	4	0.78	0.85	−0.40
Total	—	2.13	2.15	+0.12†

* Influent: 0.59 lb casein and 0.83 lb lactose per 24 hr.

† Sludge accumulated or discharged.

an ultimate value of 630 mg/l. Thus, the 5-day BOD values would yield a purification degree of 98.5 per cent, whereas the comparison of the ultimate values would indicate a purification degree of 96.8 per cent.

It is interesting to speculate that while total oxidation, per se, is not possible, it would be conceivable to operate a system with a lower influent BOD and have an activated sludge discharge of approximately 20 mg/l with a BOD of less than 10 mg/l. Such an effluent probably would not be objectionable to many receiving streams. While total oxidation is not technically possible, the phenomenon would appear to exist and all of the advantages of such a system could be enjoyed. However, as Symons and McKinney (5) showed, the minimum accumulation of non-oxidizable sludge would occur only when there is sufficient nitrogen in the system. To assist certain waste systems, a nitrogen supplement might be needed.

Conclusions

From the results of studies on metabolic energy balances in a multiple-unit total oxidation system using dry skim milk as a source of organic matter, the following conclusions were reached:

1. Total endogenous oxidation is not possible within reasonable times and sizes of treatment systems, as there is a residual material remaining equivalent to 20 to 25 per cent by weight of the new activated sludge produced.

2. The influent ultimate oxygen demand has 58 per cent of its weight appearing as new activated sludge in a continuous influent system.

3. The actual endogenous loss is 2 per cent per day of the total weight of activated sludge in the system.

4. The accumulation of non-oxidizable sludge is 0.6 per cent per day of the total weight of activated sludge in the system.

5. The "equilibrium" weight of activated sludge in such a system is 14 times the influent weight per day.

Acknowledgment

The research reported herein was made possible by a grant from the National Institutes of Health, U. S. Public Health Service.

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Industrial Wastes

EXPERIMENTAL SPRAY IRRIGATION OF PAPERBOARD MILL WASTES *

By Harold C. Koch and D. E. Bloodgood

Respectively, Technical Director, Auglaize Division, Weston Paper and Manufacturing Co., St. Marys, Ohio; and Professor of Sanitary Engineering, Purdue University, Lafayette, Ind.

It was necessary for the Auglaize Division Mill of the Weston Paper and Manufacturing Company to look for means of alleviating the conditions where the mill wastewaters were discharged into a small stream flowing through the city of St. Marys, Ohio. Following a careful study of the mill wastes, of the pollution abatement requirements, and of the various waste treatment or disposal procedures, it was decided that spray irrigation disposal offered better possibilities of filling the needs than other methods. However, the applicability of spray irrigation for the disposal of this particular type of waste had not been fully evaluated. It was, therefore, proposed that the desired data and information be developed through experiments with full-scale equipment operated with a limited portion of the waste from the mill. This paper is a report of the experiments conducted up to this time.

Source and Nature of Wastes

The mill produces on two cylinder type paper machines grades of paperboards intended for containers of various kinds. It may be classified as a linerboard mill since the principal product is the paperboard used as the inner and outer facings in the manufacture of corrugated board for containers. Other grades also made, though in smaller quantities, are paperboards for solid fiber boards, boxboards for single wall boxes, and papers for winding into paper tubes and paper cans. A portion of the fibrous raw materials used is classified as secondary stock; that is, the fibers have been previously used in making other paper products such as corrugated boxes. The remainder of the fibrous materials is made up of previously prepared wood pulps. There is no cooking or washing of stocks involved, and the principal sources of the wastewaters are from the paper machines.

The suspended solids in the mill wastewater are made up principally of paper fibers which essentially are very short, and of some non-combustible fines quite varied in nature. The wastewater contains about 240 ppm or 2 lb/1,000 gal of suspended solids. Included with these solids are starches, cellulose degradation products, rosin, lignin and some inorganic chemicals such as aluminum sulfate, basic silicates, and spent chemicals from water softening reactions. The wastewater has a BOD from 200 to 400 ppm, and the pH range is from 7 to 8. A temperature of about 90°F appears to be a fair average for the total mill wastewaters.

Stream Receiving Waste

The waste from the mill goes into the St. Marys River, which has a relatively

* Presented at the 1958 Annual Meeting, Ohio Sewage and Industrial Wastes Conf.; Toledo, Ohio; June 18–20, 1958.

FIGURE 1.—The St. Marys River a short distance below the mill.

small flow at this point. In the dry summer and early fall months, the river has been unable to assimilate the waste it received. Figure 1 shows the river a short distance below the point where the waste from the mill enters. This photograph was taken in March of 1958 at a time when the river stage was six inches higher than is usually noted during the summer and fall months.

Wastewater Reductions Within the Mill

As is usual in all paper mills, large quantities of waters are recirculated at the paper machines. The first step taken by paper mills to abate pollution is to close the system. Since large volumes of water are normally recirculated at paper machines, this process of closing the system becomes an expansion of the reuse process throughout the mill. To do this, white water, which is water used at least once in the process, is returned to an earlier stage of the process and used in place of fresh water. The result is a proportionate reduction in the total volume of water discharged and in the total amount of suspended solids lost, and to a lesser degree in the total amount of soluble solids discharged.

Choice of Disposal Method

The reductions accomplished within the mill were, however, not sufficient to prevent excessive overload to the stream; therefore, some means for treating the remaining waste was needed. Consideration was given to treatment by sedimentation, but the indications were that this method of treatment would not be adequate, and, furthermore, a sludge disposal problem would accompany sedimentation. Chemical coagulation could be expected to give a greater degree of purification, but the sludge problem would be more complicated and there would also be a high operating chemical cost. The use of existing biological oxidation methods was not indicated for this situation. Spray irrigation has been used successfully for the disposal of a variety of industrial wastes such as those from canning and milk plants. Since it was predicted that the use of this method would eliminate sludge disposal problems and would insure good removal of

FIGURE 2.—Mill site and portion of land used for experimental spray irrigation. Irrigation field in upper right across Miami and Erie Canal.

BOD and suspended solids, it was selected for experimental development.

Land for Disposal Experiments

The amount of land required per unit volume of waste to be disposed of had to be determined by the experiments. The first consideration was, therefore, to have sufficient land on which to carry on full-scale experiments with a portion of the wastewater. Since space was not available on the mill property, additional land was purchased. It was fortunate that the mill is located near the outer edge of the city and near the farm land found to be available. Figure 2 shows the mill site and a portion of the land acquired for the experiments on the opposite side of the Miami and Erie Canal. There are

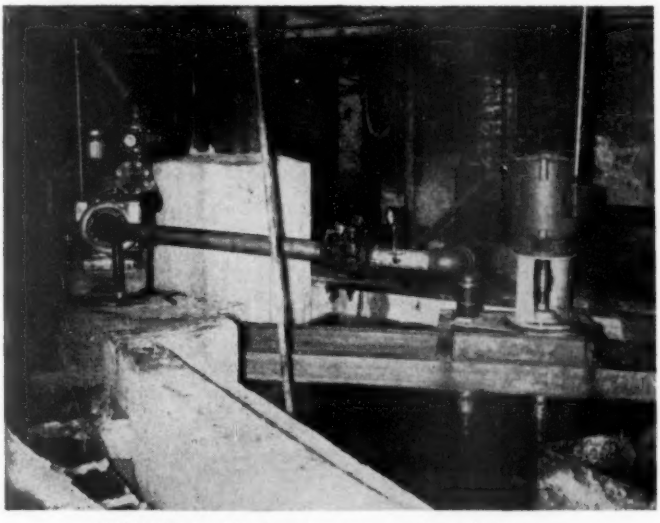

FIGURE 3.—Wastewater sump and vertical pump.

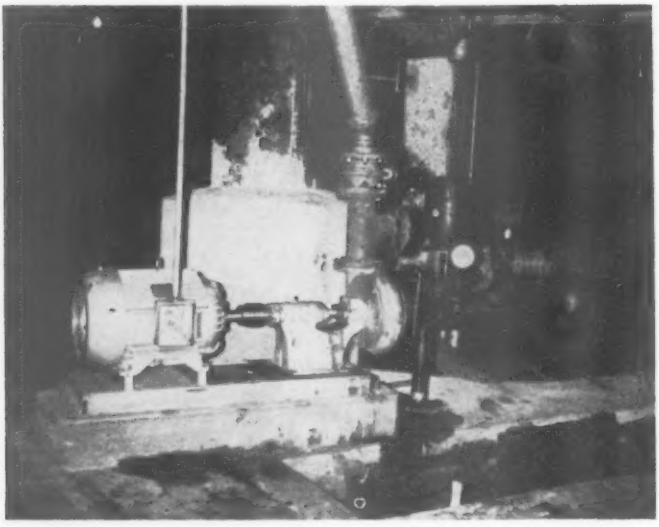

FIGURE 4.—Stationary screens and horizontal pump alongside wastewater sump.

52 acres of farm land in this experimental area which has been regularly cultivated for some years, and at the time of the purchase was producing crops of alfalfa, timothy, corn, and soy beans. The topography of the land is somewhat rolling, and the top soil has been described as a brown silt loam. Gravel appears near the surface in some places.

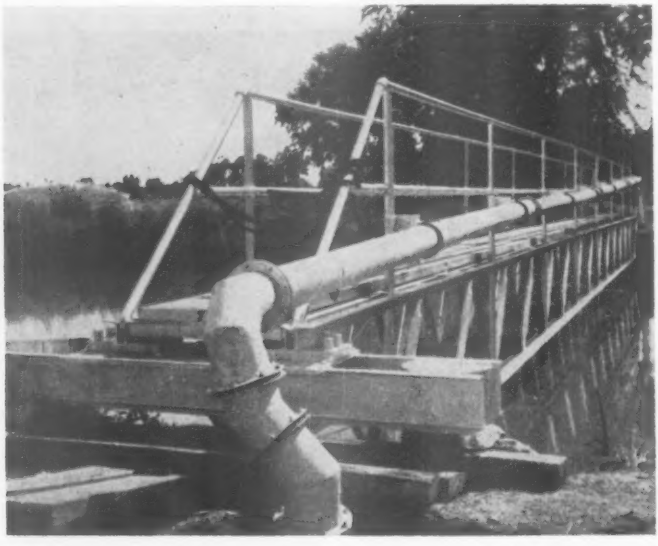

FIGURE 5.—Foot bridge used to support wastewater pipe across canal.

Collection and Transfer of Wastewater

The mill wastewaters were already collected into one ditch in the mill basement, therefore it was a simple problem to get a representative sample of waste for the spraying experiments. An open area along the side of the collection ditch was converted into a pump sump with a capacity of 2,200 gal. A rectangular opening with a sliding steel gate for closure was constructed to connect the wastewater ditch to the pump sump. Since pieces of paper stock were known to find their way into the ditch occasionally, it was felt necessary to protect the pumps and spray nozzles with some means for screening the waste. This was accomplished by installing three screens in slide supports paralleling the ditch wall in front of the sump opening. The screens were made of ½-in. hardware cloth supported on light steel angle frames 28 in. long and 24 in. wide. These were made so that they could be lifted out for cleaning or repairs. After some use it has been found that these screens are most conveniently cleaned by brushing them with a long handled steel brush, while in place. A removable dam across the ditch below the opening is used to raise the wastewater level on the screens, and also to lower the wastewater level to aid in flushing away the materials loosened when the screens are cleaned.

Two pumps in series are used to deliver the wastewater to the nozzles in the field. The first pump is a 4-in. vertical wet pit sewage pump with nonclog impeller. The second is a horizontal pump otherwise similar to the first. The pressure developed by the two pumps is 90 psi. The sump and the vertical pump are shown in Figure 3, and Figure 4 shows the screens and the horizontal booster pump.

The water is pumped to the field in a 6-in. diameter galvanized steel pipe. The pipe was supported along the walls of the existing sewer for a distance of some 50 yd, and then was brought to the surface and laid on the ground. A convenient passageway from the mill buildings was thus provided for the pipe.

The problem of crossing the canal separating the mill and the irrigation

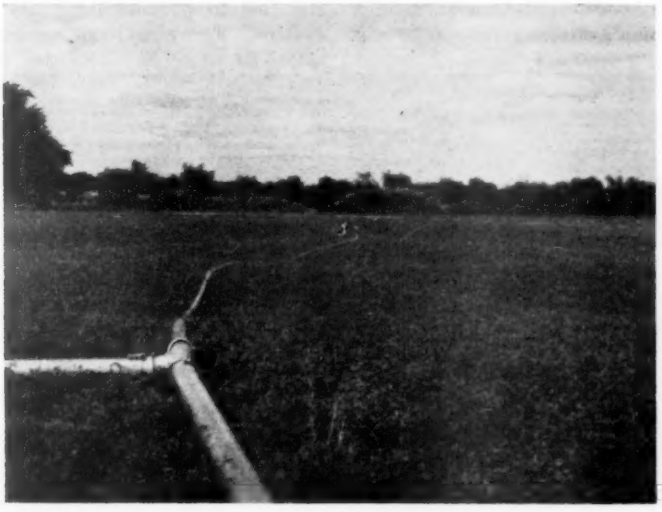

FIGURE 6.—Aluminum irrigation pipe in operation in field of alfalfa.

FIGURE 7.—Spray nozzle in position for use (Rainbird No. 90).

field was solved by installing a 64-ft single span steel foot bridge to support the pipe and to provide a convenient access to the field from the mill. Figure 5 shows the bridge.

Beginning at the irrigation field, the 6-in. galvanized pipe was reduced to 5-in. aluminum tubing with galvanized steel couplers. Aluminum pipe was selected because of its convenience in moving and handling. The pipe was laid directly on top of the ground to give the desired distribution to the sprinklers. Figure 6 is a photograph of the pipe in the field. The pipe sections are 30 ft in length and are equipped with quick-coupling hooks. The sprinkler control and adapter units have individual built-in control valves, but other gate valves were placed in the line to provide flexibility to the system. For winter use, drain valves

FIGURE 8.—Single spray nozzle in operation.

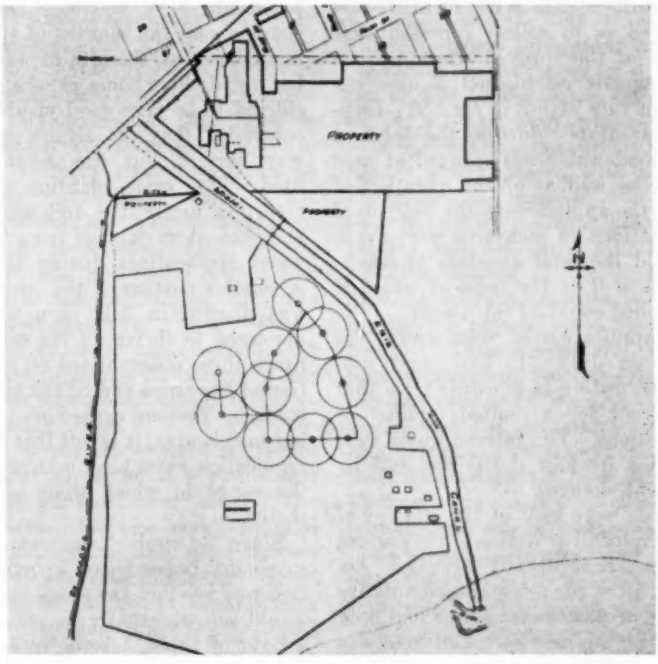

FIGURE 9.—Plan layout of distribution system and sprinkler locations.

and additional gate valves were added to the system.

Since the sprinkler adapters provide a quick-acting connection, it was not necessary to have a nozzle for each location provided. It was found that for a system using one sprinkler at a time, it is practical to operate with only three nozzles on hand. Figure 7 shows one of the sprinkler heads in place.* Each sprinkler head has three nozzles with openings of $^{13}/_{16}$, $1/2$, and $1/4$ in., respectively. This sprinkler discharges 238 gpm at 70 psi and 260 gpm at 90 psi. Figure 8 is a photograph of one of the sprinklers in operation.

Experimental Irrigation

The portion of land selected for the experiments covered about 14 acres on which alfalfa seeded the year before was growing. Ten spray locations were provided. These were spaced about 210 and 240 ft apart, except for three, one of which was spaced at a lesser interval and two of which were spaced farther apart to better suit the contour of the land. Figure 9 is a diagram of the distribution system and of the sprinkler locations. The sprinklers rotated a full circle distributing water over a radius of 100 or more ft. Each, therefore, applied water to a minimum of seven-tenths of an acre of ground.

The operational pattern followed a schedule of applying waste from two different sprinkler locations each day, five days a week. For example, sprinklers numbered 1 and 2 were used on Mondays, sprinklers 3 and 4 on Tuesdays, and so on. The schedule also called for applications of two hours duration on some locations and of three hours on others.

The application rate was checked by measuring the depth of water collected

* Rainbird No. 90.

in flat-bottom cans with vertical sides placed so as to collect representative samples of the sprayed waste. These measurements established a unit application rate of 0.7 in./hr. By keeping an accurate record of the dates on which wastewater was sprayed at each location as well as of the duration of time of the applications, the individual precipitations on each area were available, and the total amounts of wastewater as well as the rates at which it was applied could be calculated.

The application of wastewater was started on July 31, 1957, and continued according to schedule from that time except for a limited number of interruptions. The interruptions were occasioned by mill shutdowns and by equipment changes.

Records were kept of the amount of natural rainfall as well as of the amount of wastewater applied by spraying. On May 31, 1958, the minimum cumulative quantity of wastewater which had been sprayed on any one sprinkler area was 36.0 in., and the greatest was 51.6 in. Converting these data to average application rates sprayed per calender day during any one uninterrupted period shows a range from 0.13 in. for the lowest to 0.48 in. for the highest. Adding the average rainfall of 0.08 in./day which fell during the uninterrupted spraying periods, the average total daily quantity of wastewater received by the land ranged from 0.21 to 0.56 in. Using an average of all precipitation figures for the entire experimental period reveals an application rate of 0.28 in./day of wastewater, plus rainfall. Observations made during approximately nine months of experimentation indicate that this rate of application can be increased, although the degree of increase must await further experimental work.

Effect on Crops and Soil

Most of the area of land sprayed was covered with alfalfa which had been planted the year before the experiments were started. During the summer and fall months of the experimental period, the alfalfa was cut and harvested three times at what was considered to be very good yields. It was concluded that the alfalfa was in no way harmed but was actually benefited. This same planting of alfalfa returned nicely the following spring and showed no damage from the wastewater applications during the winter. A smaller portion of the land sprayed was planted in field corn which also appeared to thrive on the wastewater. Since these observations on the condition of the crops and of the yields were made by persons experienced in farming in this area, it is felt that the water application rates have been well within the range in which these plants will thrive.

Since the applied wastewater carries suspended paper fibers, a common question was whether the crops and the soil would not eventually be covered with a layer of paper. Actually, at no time has it been possible to find more than a few fibers adhering to the leaves of the plants. This has been true even directly after a spraying period. Except at a few small isolated areas where the lines were regularly drained, no fibers have been found lying on the surface of the ground. The isolated concentrations at some of the drains have quickly disappeared.

The desirability of determining the effects on the chemical constituents of the soil has been recognized and analyses of soil samples have been made and others will be made periodically as the experiments are continued. Although the experimental data presently at hand in this respect are not complete enough to indicate any trends, no serious problems are anticipated.

Seasonal Problems

Another question commonly asked is that concerning problems encountered in the winter months. Experience has shown that the low temperatures en-

countered some three months each year do bring problems which need consideration. These problems, however, are generally limited to the distribution system. By laying the pipe lines on grades which will accommodate drainage and by providing shut-off valves and drain valves in the lines, it has been found possible to avoid freezing in all parts of the system. The temperature of the mill wastewater is 90°F and readings at the far end of the lines showed a drop of only 2 to 3°. Freezing, therefore, could occur only in dead ends of the pipe, and this situation was avoided by the use of adequate valves and drains.

In the winter the sprayed water did freeze into icicles on tall plants and trees, but no harm was noted. The frozen ground did also have a reduced rate of absorption, and some surface runoff and ponding did occur. However, none of the ponds formed more than a paper-thin crust of ice which indicated that the water was being absorbed. It was interesting to note that the alfalfa returned nicely after the first winter's application.

As part of the continuing investigative program the land spray area has been further developed by the addition of piping and fittings at a cost of $10,479. Thirty-three spray areas have been used for test purposes during the last half of 1958 and the early months of 1959. The land which the first year was in annual crops has now been cultivated and seeded with a mixture of legumes and grasses. The distribution system in the field has been expanded and will provide 32 sprinkler locations instead of the 10 described here. A waste application rate of 0.56 in./day has been attained for an entire month. When the natural precipitation is included, for the same period the rate was 0.74 in./day. It is believed that the maximum application rate permissible, without injury to the land, has not as yet been determined. Further expansion of facilities is planned and will be completed in 1959.

By thus expanding not only the system but also the program it is expected that a more complete evaluation of spray irrigation as a means of stream pollution abatement for this type of waste will be gained. At the time of this report, it is felt that the prospects for developing a spray irrigation disposal method which will satisfy the needs of this mill are very good.

CHICAGO ADOPTS ZIMMERMAN PROCESS

The Metropolitan Sanitary District of Greater Chicago in June announced plans for installation of the Zimmerman Process for disposal of sludge at the West-Southwest Treatment Works. This operation utilizes a combustion principle for sludge handling. The contract, in the amount of $11,870,000, provides that the Sterling Drug Company will design, engineer, and build the plant, furnish and install all equipment, test its operation, and provide instruction for operating personnel.

The completed plant will have a handling capacity of 200 tons of sludge per day. It will consist of four units, each of 50 tons capacity and each having a full complement of equipment. One turbo-generator for power development will be included. The 200-ton capacity represents more than 20 per cent of the Sanitary District's total treatment capacity.

Testing is scheduled within 18 months and final completion is to be within 24 months.

CONDENSATES, QUENCHES, AND WASH WATERS AS PETROCHEMICAL WASTE SOURCES*

By Harold F. Elkin

Sun Oil Company, Philadelphia, Pa.

This is one of several papers from an Industrial Wastes Symposium titled, "The Petrochemical Industry." The first three papers were published in This Journal (**31**, 3, 274; **31**, 5, 574; and **31**, 6, 712). Other papers in the series appear on pages 841 and 846 of this issue.

A previous paper in this symposium has indicated the heterogeneous nature of wastes produced by the basic petrochemical processes (1). These processes start with natural gas, crude oil, or various petroleum cuts, and by cracking yield ethylene, propylene, butadiene, butylene, and other chemicals. In the cracking process, steam is used for a number of reasons and may be introduced at several points. When the cracked gases are cooled the resulting condensates contain oils, carbon, and numerous compounds in solution. The principal pollution problems created by disposal of condensates are those of taste, odor, and oxygen demand. Table I summarizes a typical chemical evaluation of this type of waste.

The waters from secondary petrochemical processes usually are less complex (2) than the basic process wastes because relatively pure raw materials are dealt with.

Treatment and Disposal

The treatment fundamentals applied to petrochemical wastes are not unlike those employed in the oil and organic chemical industries. Before utilizing disposal techniques, however, the responsible investigator explores and evaluates the alternatives of waste recovery and utilization and process modification until he is satisfied that treatment and discharge represent an economic as well as a technical choice of alternatives. The types of treatment may be classified as follows:

1. Chemical treatment.
2. Chlorination.
3. Catalytic oxidation.
4. Filtration and solids separation.
5. Burning.
6. Stripping.
7. Biological oxidation.
8. Deep-well disposal.
9. Discharge to municipal sewer systems.
10. Dilution in streams and oceans.

TABLE I.—An Example of Characteristics of Thermal Cracking Wastes

Waste Characteristics	Feed		
	Crude Oil*	Propane†	Gasoline‡
Flow (gpm)	350	100	190
COD (ppm)	880	2,800	500
5-day BOD (ppm)	230	257	440
Oil (ppm)	200	2,600	—
Phenols (ppm)	20	26	25
Odor threshold	100,000	125,000	16,700

* Water from purge of recycled quench water.
† Water from steam condensate.
‡ Water from condensate after oil quench.

* Presented at the 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

TABLE II.—An Example of the Results of Biological Treatment of Petrochemical Wastes and the Effects of Postchlorination

Item	Influent	Effluent	Effluent +25 ppm Cl_2
COD (ppm)	500	60	—
BOD (ppm)	440	5	—
Phenol (ppm)	25	1.0	—
Odor threshold	16,700	5,000	3,570
Fish taste threshold	300	300	150

Chemical Treatment

In chemical treatment such familiar techniques as neutralization of acid or alkaline waters are normally employed before subsequent treatment or discharge (3) (4) (5). Common sources of this type of waste are (a) ethylene consumers where alkylate is water-washed to remove acidic components and (b) vinyl chloride manufacturing operations where acid and alkaline waters may be equalized. In some cases the neutralization may permit recovery of usable by-products, such as acid-oils, from spent caustic wash waters.

Chlorination

Chlorination may be used for oxidative destruction. Perhaps the best-known example occurs in hydrogen cyanide production where alkaline chlorination is employed to consume aqueous cyanide wastes (5) (6) (7).

Chlorination may also be used after major treatment as a final clean-up procedure to reduce oxygen demand, and taste and odor effects of the effluent (Table II).

Catalytic Oxidation

An outstanding application of the catalytic oxidation process to the dilution of organic wastes from ethylene glycol synthesis has been described by Oliver (8). The concentration of organics in the waste was insufficient to support combustion without the use of additive fuel or the installation of heat-exchange equipment. A copper chromite catalyst was employed to permit oxidation at a low temperature. The catalytic reaction took place with the inlet gas stream at 250°C and outlet gas at 550°C. Approximately 97 per cent destruction of organics was reported.

Filtration and Solids Separation

Filtration has been used in the treatment of vinyl chloride wastes (6). Copper in acrylonitrile waters was percolated through a bed of aluminum where it deposited and displaced the aluminum. In the manufacture of latex from styrene and butadiene, reactor washes and screening-process wash, as well as storage clean-outs, require a holding basin or tank which feeds continuously to a coagulation basin. This treatment is followed by sedimentation.

Burning

Incineration and burning procedures are normally associated with solid or concentrated liquid waste. However, dilute liquid wastes, such as condensates, have been handled, at least temporarily, by injecting them into existing burner fire-boxes or high-temperature stacks. They have also been used as a quench water in catalytic regenerators. Use of these procedures, however, requires that consideration be given to the possibility of air pollution and the necessity for installing corrosion-resistant equipment.

Stripping

The literature contains numerous references to the use of stripping to remove objectionable components in waste streams (5) (6) (9) (10). In a styrene plant, the catalytic dehydrogenation of ethylbenzene is carried out in the presence of steam. The resulting condensate is saturated with 0.1 per cent aromatics which are removed by steam stripping. Acryloni-

trile waters containing 100 ppm of product are reported to have been steam stripped to a bottoms content of 10 to 15 ppm. Stripper overhead is burned in an incinerator.

Biological Oxidation

Many oil and chemical wastes were originally thought to be toxic to biological treatment systems. Today, however, bio-oxidation systems are in common use and are considered to be the ultimate procedure for the stabilization of organic wastewaters. Phenols, perhaps the most prevalent of the aromatics in industrial wastewaters, were successfully treated on trickling filters by the Dow Chemical Company at Midland, Michigan, during the 1930's (4). An activated sludge plant for treating mixed organic wastes was constructed by the same company in 1946. The first-known plant-scale facility for the bacterial oxidation of phenols from an oil refinery operation was accomplished at the Sun Oil Company plant at Sarnia, Ontario, in 1954. An extended aeration process was employed. These plants were pioneers and their success led to the establishment of numerous other biological treating units in other industries.

Extensive laboratory work and pilot-plant studies preceded the designing of the bio-treatment plants now in construction or in operation in the petrochemical industry (11) (12) (13). Phenolics and other aromatics in concentrations up to 500 ppm have been found tolerable in activated sludge. Bacterial floes have been reported to be acclimatized to 100 ppm cyanides. In general, primary and secondary alcohols and aldehydes are readily oxidized with a major portion of the BOD and COD removed within 4 hr of aeration time. Tertiary alcohols, methylal and glycols are more resistant and require a longer period for sludge acclimatization.

An intensive pilot study was made on a composite wastewater containing a mixture of acetic acid, acetone, acetaldehyde, formaldehyde, methanol, propanol, butanol, and propylene glycol with a combined BOD of 11,000 ppm and a COD of 30,000 ppm (13). A trickling filter was found to be very effective at a BOD loading of 37 lb/1,000 cu ft. Activated sludge in pilot operation achieved 99 per cent removal at BOD loadings of 200 lb/day/1,000 cu ft, and 80 per cent removal at loadings of 400 lb/day/1,000 cu ft.

Among biological treatment plants for petrochemical wastes which are in operation or in the planning stage are those at Dow Chemical Company in Michigan, Chemstrand Corporation in Florida, Celanese Corporation in Texas, and at Union Carbide Chemicals Company in West Virginia. Typical waste treatment plant operating data are shown in Table II.

Stabilization ponds have also been used with success. One plant clarifies process wastes by oil skimming, flocculation, and chlorination, and follows this with treatment in a stabilizing lagoon where BOD reductions of 95 to 99 per cent and COD reductions of 75 to 96 per cent are accomplished (7). The BOD removals are achieved at loading rates of 100 lb/day/acre. Another plant constructed oxidation ponds for 55 mil gal of wastewater, the equivalent of 18 days retention in 1954 (14). These basins have been reported to remove 90 to 95 per cent of the BOD at loadings of 75 lb/day/acre.

Deep-Well Disposal

Underground disposal of industrial wastes has met with mixed success due to lack of definitive evaluation techniques. There may be no assurance of permanent utility for a given well. The sealing of potable-water sands may be costly and in many cases impractical. When disposal wells must be abandoned, replacements are expensive.

Nevertheless, deep-well disposal has a legitimate place in wastewater disposal when properly controlled. Brines

and caustic waters containing sulfides and phenolics have been successfully deposited underground and, with proper controls, additional liquid wastes could be similarly discharged.

Discharge to Municipal Sewer Systems

Chemical wastes that are easily oxidizable by biological processes after neutralization, such as alcohols and carboxylic acids, are being discharged to municipal sewage treatment plants in considerable quantities (4). Phenolics can be included in limited quantities. Discharge of oxidizable inorganics must be limited to avoid release of damaging gaseous products (such as sulfides). Discharge of toxic substances, such as salts of heavy metals and cyanides, must be rigidly limited. Pretreatment of industrial effluents is often required before discharge to sanitary sewer systems.

Dilution

Disposal of reasonable quantities of industrial waste components to receiving waters of large volume may represent a legitimate effluent-control measure providing no higher use of the receiving water is affected. Dilution is certainly of assistance in assimilating residual waste components which remain after treatment since facilities for such treatment are seldom 100-per cent efficient.

An interesting method of disposal by dilution is discharge to the sea which is currently receiving much attention. The appropriate authorities should be consulted when this method of disposal is contemplated. An outstanding example of ocean discharge off the Gulf Coast has been described by Eberman (15). A combination of petrochemical wastes, including chlorinated hydrocarbons, caustic soda with sulfur and phenolic compounds, and sludges, has been hauled to sea in a 6,000-bbl-barge and discharged at the 400-fathom line. The initial cost of a barge is approximately $10 per bbl. With maintenance and towing established at approximately $3,000 per trip, the disposal cost ranges from $2.00 to $3.50 per ton, including provision for 10-yr amortization, carrying charges, and fixed charges. Oceanographic studies have been conducted to check effects on marine life.

Conclusions

The complexities of the disposal of petrochemical aqueous wastes are, for the most part, familiar to sanitary and industrial waste technicians. However, the wide variety of petrochemical operations calls for much study and individual consideration of the problems peculiar to each operation. The rapid growth of this new industry will undoubtedly stimulate the active investigation of new waste-handling techniques and modification of existing procedures.

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MEETINGS OF INTEREST

July 12–17 **American Water Works Association,** Civic Auditorium, San Francisco, Calif. Harry E. Jordan, Secretary, American Water Works Association, 2 Park Avenue, New York 16, N. Y.

July 22–25 **First International Conference on Waste Disposal in the Marine Environment.** Department of Conferences, University Extension, University of California, Berkeley 4, Calif.

Aug. 27 **State Chamber of Commerce Water Supply Conference,** Abraham Lincoln Hotel and St. Nicholas Hotel, Springfield, Ill. J. G. Ronchetto, Illinois State Chamber of Commerce, 20 N. Wacker Drive, Chicago 6, Ill.

Sept. 8–10 **Annual Water and Sewage Plant Operators Short Course,** University of Maryland, College Park, Md. W. M. Bingley, 2411 N. Charles Street, Baltimore 18, Md.

Sept. 13–18 **American Chemical Society,** 136th National Meeting, Atlantic City, N. J. H. B. Gustafson, P. O. Box 5033, Tucson, Ariz.

Sept. 14–19 **Symposium on the Treatment of Waste Waters,** Kings College, Newcastle upon Tyne, University of Durham, England. Peter C. G. Isaac, Public Health Engineering Section, Dept. of Civil Engineering, Kings College, Newcastle upon Tyne, England.

Sept. 20–23 **American Public Works Association,** Olympic Hotel, Seattle, Wash. Robert D. Bugher, Executive Director, 1313 E. 60th Street, Chicago 37, Ill.

Sept. 21–25 **14th Annual Instrument-Automation Conference and Exhibit,** Instrument Society of America, International Amphitheater, Chicago, Ill. H. S. Kindler, Director of Tech. and Educational Services, 313–6th Avenue, Pittsburgh 22, Pa.

Oct. 19–23 **American Public Health Association,** Annual Meeting, Convention Hall, Atlantic City, N. J. Dr. Berwyn F. Mattison, Executive Secretary, APHA, 1790 Broadway, New York, N. Y.

Oct. 19–23 **American Society of Civil Engineers,** Annual Convention, Hotel Statler, Washington, D. C. W. H. Wisely, Executive Secretary, ASCE, 33 West 39th Street, New York 18, N. Y.

TARS, SPENT CATALYSTS, AND COMPLEXES AS PETROCHEMICAL WASTE SOURCES *

By Jack T. Garrett

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This is one of several papers from an Industrial Wastes Symposium titled, "The Petrochemical Industry." The first three papers were published in This Journal (**31**, 3, 274; **31**, 5, 574; and **31**, 6, 712). Other papers in the series appear on pages 836 and 846 of this issue.

Tars, spent catalysts, and catalyst complexes are usually disposed of by burning, burying, or by direct discharge to streams. Disposal of these troublesome wastes is not always simple since some of the plants now in operation are highly complex and the result of much expensive research.

Petrochemical processes usually involve the reaction of certain components catalytically to produce a crude intermediate product which is subsequently distilled to produce the desired end-product. These processes, which use petroleum-derived raw materials, produce an almost endless number of chemical products. All these products and processes are included within the meaning of the difficult-to-define term of "petrochemical" or "petrochemical process." In addition, there are many chemical processes using coal-tar-derived intermediates which are similar to the so-called "petrochemical processes."

Scope of Problem

A hypothetical process may be considered in which an organic liquid *A* and a gas *B* are reacted catalytically to produce crude *AB*. The crude material is subsequently distilled to give the refined product *AB*. There are several places in this process where troublesome disposal problems could arise. The still tars from the distillation step would most certainly constitute such a problem. The spent catalyst, in the form of an organic catalyst complex, a spent-catalyst tar, or spent dry-bed material, would pose another disposal problem, the extent of which would depend on many factors. Before an adequate disposal process could be designed, intelligent answers would have to be found to questions such as:

1. In what form is the spent material when removed from the process?
2. How much of the spent material is produced per unit of time or product?
3. How toxic is the spent catalyst or its combustion products?
4. Can the catalyst be regenerated or can some recoverable product be produced from the spent material?

In considering the disposal of the distillation tars from the simple hypothetical process described, many other factors would have to be taken into account. For example, the consistency (viscosity, specific gravity, etc.) of the tar would have to be known before the necessary equipment to move it from the process site to the disposal site could be designed. The composition of the tar should be understood so that the necessary disposal equipment could

* Presented at the 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

be operated without creating air pollution or handling problems. The amount of tar produced per unit of time would have to be determined before designing the size of the disposal equipment.

Incineration

Open-Pit Burning

Incineration is the method most frequently used for the disposal of troublesome materials and it is probably the oldest waste disposal process known to industry. Some of the present-day uses of this process are no different than they were hundreds of years ago. This does not mean, however, that such uses are wrong or necessarily troublesome. Open-pit burning, which is the simplest and least expensive method of incineration, is as widely practiced today as it was two generations ago. To burn organic materials properly in this fashion requires good planning and proper control, however. Open-pit burning should be done under strict supervision and adequate fire-extinguishing equipment should always be available. The smoke plume from this operation should be kept under observation and the fire extinguished when the wind shifts sufficiently to bring the plume over populated areas. Unsupervised open-pit burning has frequently caused serious air pollution problems to those plants foolish enough to follow this practice.

A modified method of open-pit burning has been developed in the petrochemical industry in recent years. This method employs open ground-level burners mounted in areas where fire is no problem and where the organic tars to be burned can be stored. These burners employ proper oxygen balance and the organic tars can be burned with a minimum of visible evidence. These installations, of course, require pumps, piping, ignition sources, and, very often, a secondary fuel supply but they provide an economical method of incinerating many troublesome wastes.

Metallic Materials

Many catalyst tars, complexes, and distillation residues contain metallic materials. These metals or their oxides will be discharged into the air effluent from the incinerator installation if provision is not made to trap them. When the concentration is very low, the discharge of this material probably does not constitute a hazard because of the dilution effect. However, in many incinerator installations where metallic materials are burned, the metallic residues should be collected and removed from the exit gases before discharge. In this way metallic materials, such as nickel, copper, and platinum, can be recovered for resale and substances which constitute health or corrosion hazards, such as chlorine, nitrogen, and sulfur, may be removed. It is very often necessary to scrub the effluent gases to remove materials of this type.

Sulfur and Flyash

Sulfur-containing tars are probably the most troublesome to incinerate from an air-pollution standpoint. If the exit gas concentration of SO_2 is high enough, air pollution is distressingly evident in the surrounding area. The discharge of the exit gases from incinerating chlorinated tars is also very troublesome from the corrosion standpoint. These gases have a tendency, when discharged into humid atmospheres, to hydrate quite rapidly and settle out as a hydrochloric acid mist. The discharge of small quantities of oxides of nitrogen or sulfur does not ordinarily constitute an air pollution problem if these materials are dilute enough in the exit gases. The maximum downwind concentrations of these compounds can be calculated by using mathematical formulas such as the Sutton or the Bosanquet-Pearson equations (1) (2) (3) and, where troublesome materials are to be discharged, such calculations should always be made.

Another problem that frequently arises in the incineration of petro-

chemical tars and complexes comes from the flyash produced by incinerating tars that contain inert materials. Tarry chemical residues frequently contain filter aids and other inert materials added during the process operation. These materials cannot be readily separated from the tars before disposal and, when the tars are incinerated, these inert substances are invariably discharged in the exit gases as solid particulate matter. If the amount of this particulate matter is great then it must be removed from the exit gases. Calculations of the possible ground concentrations aid in deciding what collection equipment is necessary. Very often a settling chamber, placed downstream from the combustion chamber, will serve to remove this material.

Design Requirements

Balanced incinerators of many different types have been designed and constructed to perform a great variety of burning jobs (4) (5). In general, they must be designed to fit the variables encountered in the specific waste-disposal project. Most chemical incinerators are designed for multi-purpose burning and frequently have provision for trash burning included as part of their design. If a balanced incinerator is needed, it should be designed, if possible, to perform all waste-burning tasks necessary in the plant. It is very often feasible to recover waste heat value from incineration of flammable materials through waste heat boilers, pre-heating equipment, etc. If the materials to be burned have acceptable characteristics, it is also possible to use these materials directly as fuels in fuel-burning equipment.

Great care must be taken in the design of balanced incinerators to be used for burning chemical tars. Such variables as the reaction time, stack height, construction material, burner sizes, recycled air, and many others must be carefully considered. For example, the type of burner selected is of great importance because these burners must accommodate the materials to be burned unless they are to be mechanically placed in the fire chamber for burning. If the proper burner is available, it is very often possible to feed highly viscous tars by steam or air atomization through burners after this material has been pre-heated to the point where consistency suitable for pumping is obtained.

The secondary air and fuel supply to balanced incinerators is important because the incinerator must have sufficient air to oxidize completely all materials that are to be burned. A secondary fuel supply is also necessary to maintain combustion temperatures and to level out uneven waste loads and prevent heat-shocking of the incinerator refractory.

In the construction of incineration equipment, the type of interior refractory used is of importance. It must be capable of withstanding the anticipated heat and corrosive attack.

The height of the stack used for combustion gases from an incinerator should also be designed with great care. The downwind concentration of any material that leaves the incinerator stack is influenced, not only by the exit gas temperature, but also by the height of the stack through which the gases exit. Very often an increase in height of a planned incinerator stack can eliminate the possibility of future air pollution problems.

Burial of Wastes

Incineration is not the only method of disposing of tars and catalyst complexes. It is perfectly acceptable practice to bury these materials in many instances. Burial is usually less expensive than incineration at the outset but becomes more expensive as more property is required. Several methods of burying waste products are being employed in the chemical industry at the present time. It is frequently possible to use the method of sanitary land

fill with the tarry or catalyst materials being mixed with earth and deposited as fill in an excavated dumpsite. This procedure may be feasible if inexpensive waste land is available. Whether or not the land so used can be subsequently used for construction sites, etc., depends on the ultimate fate of the tarry materials deposited. The possibility of the tarry materials leaching into ground water reservoirs must, of course, be explored.

A more common method of disposing of tars by burial involves placing them in waste drums and burying the drums. This procedure also presents the problem of possible ground water contamination after the drums have deteriorated and also the possibility of fire or explosion in the dumpsite.

Another common method of disposal consists of burying or dumping this type of material in public dumps which is usually just another method of incineration since most public dumps ignite flammable material to reduce volume.

In some areas it is possible to dispose of tarry materials in deep pits. This has been done in strip mine pits where the tarry materials can be placed in drums and buried under 40 to 80 ft of strip mine overburden. But this also constitutes a potential threat of contamination of the ground water supplies. Therefore, thorough knowledge of the subsurface formations is desirable before using this method.

Direct Discharge to Streams

In discharging tarry materials or catalyst complex materials by sewers to streams, great care must be taken to prevent contamination of the receiving stream. This creates a specific problem when consideration is given to including tars in wastes to streams. It is possible to dilute some of these materials, which are either water soluble or partially water soluble, to a point where they constitute no hazard in the receiving stream. However, when large quantities of non-miscible organic materials are to be disposed of, direct discharge to streams is definitely not the process of choice since to do so simply transfers the problem from the process site to the receiving stream.

In recent years the problem of disposing of tarry materials has become quite critical due to the expansion of the petrochemical and petroleum industry. Many new uses of old processes have been developed in the effort to cope with this problem.

Deep sea disposal of heavy organic tars is one of these procedures. At the present time there are companies using this procedure along the Atlantic Coast, the Gulf Coast, and the Pacific Coast. While highly toxic materials, including radioactive substances, are usually placed in containers and disposed of from ships far out at sea, it would be very expensive to dispose of large quantities of tarry materials in this manner. The Shell Chemical Company has pioneered in the establishment of a modified deep sea disposal system for organic tars. The wastes are hauled in a specially constructed barge some distance from shore and discharged directly into the Gulf of Mexico (6) (7).

Establishment of a deep sea disposal system requires that a thorough study of the marine conditions in the area of disposal be made. The effect of the material on the indigenous marine life must also be determined. Authorities in the area must have assurance that the material will neither greatly affect the marine fishing industry nor return to shore to deposit along public waterways, particularly recreational beaches. Very extensive data from recognized biological and oceanographic consultants are required by all states before approval is given to plans for disposal of wastes by this method. The National Lead Company, for example, now discharges sulfuric acid and ferrous sulfide off the coast of New Jersey. Extensive work was done by the Woods-Hole Oceanographic Institute for the

National Lead Company before this disposal method was permitted. Very detailed studies were also made for the Shell Chemical Company by the Texas A & M College before their disposal procedure was permitted by the State of Texas. Since the Texas operation is beyond the international boundary, it might be supposed that the State of Texas would have no authority in this case but this is not true. The barge that disposes of the material both originates and terminates its trips in Texas ports and, since the material might adversely affect Texas marine fishing interests or the use of recreational beaches within the boundary of the state, the state can and does exercise rights of control.

Reclamation Processes

There are many other ways of disposing of tarry materials in addition to those described above, particularly in the case of materials which contain recoverable products. Many companies engage chemical recovery firms to recover usable products from their catalyst complexes and tars. These firms can handle the tars from many different operations and usually incinerate the flammable materials that are not recoverable. In many cases, tars contain particular materials that make them salable as scrap material. For example, at one time Monsanto Chemical Company sold tar containing recoverable quantities of copper to the American Smelting and Refining Company. This company recovered the copper from these tarry materials at a smelter. Tars containing nickel and many other usable metals can also be sold to chemical scrap dealers for recovery of these valuable metals. These particular methods of disposal usually do not, in themselves, produce a profit for the company producing the tars. Often, however, they eliminate the necessity for the purchase of expensive incineration equipment and the possible creation of air pollution problems.

Conclusions

The problem of disposing of tars, spent catalysts, and complexes is a broad one. While many methods of disposal are currently used in the petrochemical industry, no panacea for disposal of these troublesome substances appears to be at hand. As is so often the case in the industrial wastes field, the disposal of tars from the petrochemical industry requires painstaking study of the composition of the particular material to be disposed of and thorough engineering work on the design of disposal equipment which will be capable of accomplishing the job successfully.

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DEFINITIVE CHARACTERIZATION OF INDUSTRIAL WASTES *

By M. B. Ettinger

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This is one of several papers from an Industrial Wastes Symposium titled, "The Petrochemical Industry." The first three papers were published in This Journal (**31**, 3, 274; **31**, 5, 574; and **31**, 6, 712). Other papers in the series appear on pages 836 and 841 of this issue.

The discharge of a waste stream suggests the water user's appraisal of the used water as less valuable for further use or reuse, particularly the specific use that he made of the water. Clearly, economic factors are the basis for determining what constitutes a valuable water asset, marginally useful water, or a waste subject to disposal. As the regulations governing the minimum quality requirements acceptable in a waste become more exacting, wastes become progressively more attractive for use or reuse in process. When water is sufficiently scarce, what is ordinarily a spent waste becomes a valuable water source as is the case at Amarillo, Texas (1).

Water Resources and Administration

Growing populations and even more rapidly growing industry leave but one choice, lower allowances of expendable water resources for each man and for each unit of industrial gain. And in this instance, water resource means water quality as well as water quantity. This is the beginning of a period of allocation of water quality consumption on a state or regional basis. Industry is doing a progressively better job of locating where there is a better supply of water in terms of quantity and presently expendable quality, and the unused water resource is disappearing. Regardless of the interim ground rules, waste quality requirements must progressively approach natural stream quality, and the attractiveness of reuse of water in process as compared to getting rid of it, will grow.

Optimum administration of water quality consumption requires much knowledge not as yet on hand. However, certain guide lines are clear:

1. There are existing quality standards for drinking water. These are at present in process of revision, and this should be a continuous activity.

2. In most streams, it is possible to choose to protect a fish population and the ground rules for doing this on a rule-of-thumb bio-assay basis are reasonably clear.

3. A cross section of the water quality requirements of industry is hard to find, but the places industry chooses to locate are informative in themselves. It is predictable that in the forthcoming era of water quality conservation and rationing, industry will give increased attention to discussion of its water quality requirements as process requisites or cost factors.

4. Where use for irrigation of crops is involved there is available a great deal of data on required water quality.

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Knowledge of what domestic sewage and treated domestic sewage adds to surface waters certainly leaves much to be desired. However, information is available to provide a good idea of the volume of sewage flow, the chemicals it brings in, and the behavior of these chemicals in the receiving stream. Further, there is a constantly improving knowledge of the nature of the infectious biological contaminants added, and the record on the containment of this infectious material by water purification certainly is good. Also, rather impressive progress is being made in improving the extent to which municipal sewage receives treatment within present limits of economically practical procedures.

Industrial Waste Data

The waste from a single industrial plant is likely to be even more complex than domestic sewage. In most cases it will contain materials which have had much less study than the fats, starches, proteins, and cellulose of sewage. The physiology of man is fixed and his living habits evolve slowly. Industrial wastes change continuously and sometimes very drastically as both process and product obsolescence result from continuing technological progress. The situation is sometimes further complicated by industrial secrecy regarding process and all that pertains to it.

While there are many reasons why there is relatively little known about industrial wastes, as compared to sewage the paucity of information does not reduce the magnitude of the problem presented by these wastes or the necessity for controlling them. There are many areas of significant progress by industry in the containment of its wastes and the description of what they are and what they will do in the receiving water. However, the information required to arrive at reasonable criteria for specific industrial discharges to streams is not coming as fast as it is needed, and some costly "best judgment" guesses are sure to be made.

Stream Criteria

The fixing of specific criteria of acceptable stream loads is an infant art which sometimes masquerades as a mature science. BOD's can be determined by the usual dilution technique or other steps may be taken in an attempt to measure this more effectively in another way. Fish toxicity may be checked with bio-assays, and tests may be made to establish whether the waste has taste and odor. After interim periods of biological stabilization or biological treatment the waste can be reexamined to see what the residue will do. Naturally, mineral content is considered in an effort to estimate effects on the mineral quality of the receiving water. In these ways it is possible to arrive at an estimate of the impact of a waste on water quality. This estimate is likely to be conservative, but it may turn out to be rash. The theories on which estimates are based consider point additions of uniform loads to a constant flow with perfect mixing, isothermal weather, uniform wind velocity, uniform daily and seasonal illumination, and several other easily discernible variables.

Part of the answer is going to emerge from better stream monitoring. Manpower is not the total answer because it is too expensive, too slow, and too limited in its capabilities. Before long it is anticipated that stream quality monitoring stations able to supply a continuous record of temperature, conductivity, turbidity, pH, and dissolved oxygen will be in common use. Every component of this potential station is now available or nearing perfection. Within a year or two it is hoped that there will be such a pilot station operating. Eventually it would seem desirable to equip the whole water quality basic data program.

However, stream monitoring cannot furnish the total answer. The tend-

ency is to saturate the banks of the major waterways with industrial and domestic population. There are still gaps, but there also are an increasing number of major industrial aggregations. The assessment by stream monitoring of one city or one industry as part of the integrated stream load is a practical impossibility in many important areas even now.

Water Quality and Accountability

The allocation of water quality use carries with it the necessity for establishing the principle of accountability. It is rarely possible to look at a low oxygen level on a meter chart of a report of bad tastes and odors from a water plant and associate it with a particular pollution source or combination of sources. Such evaluation requires an ability to associate specific causes and effects. Each industry, for its own protection and as a responsible organization and a good citizen, needs to further develop a program of monitoring its own wastes, regulating and controlling their quality, and detailing their composition. Data on volume, composition, and a sound assay of the effect of the waste on stream use are reasonable prerequisites for a petition to use surface waters to receive wastes.

Stream Data Needs

Existing knowledge of pollution effects is much better than knowledge of causes. Sometimes cause and effect are many miles apart in distance, days apart in time, and attributable to materials from multiple sources which are present in micro-concentration along with many other materials which must be given equal consideration as possible causes of the difficulty. Further, the chemical composition of the primary source of difficulty may be altered in transit. The first and most obvious approach, when the problem occurs, is to try to find out exactly what materials are present in water of degraded quality. Here the hopeful analyst finds the literature filled with a large collection of good procedures. But most of them work only when the material sought is present in the sample in huge concentration, as compared to actual stream concentrations. The micro-procedure is usually suitable for use on small samples, but it is not a procedure suitable for detection of materials in micro-concentration.

The answer is not to develop an infinite collection of procedures good for the definitive analysis of every chemical that might be found in water. This costs too much and takes too long. There may be a need to seek or develop methods for specific materials, but it must be known what to determine before this kind of effort can be afforded. The carbon filter technique is beginning to narrow some of the gap for many chemicals, because it allows the change from micro-concentration in a huge sample into macro-concentration in a small sample, and permits the use of available chemical procedures. So far, work has been done with small carbon filters which have permitted the use of water samples of the order of 5,000 gal (2) (3). The extension of this program has also been described (4).

The use of new equipment soon to be available at the Robert A. Taft Sanitary Engineering Center will mean that the existing carbon filter will be scaled up by a factor of 100. Where now a few grams of organic concentrate are obtained, it now will be possible to get a pound or so with the new apparatus. Enough material will be recovered so that long term studies can be made of the toxicity of the aggregate or any chemically or physically defined fraction thereof. The powers of analysis and search for causes should be vastly extended by this new gadget. It is expected to use an unlimited array of macro-chemical procedures in the examination of pollutants recovered from river water. The prospect of this

powerful tool is exciting and it is anticipated that much will be accomplished with it.

Summary

Earlier in this discussion the opinion was expressed that water quality rationing on the basis of economic factors will emerge as competition for the right to consume water quality becomes more intense. However, it is not meant to imply that the naked economics of cost factors are going to be the sole determinant.

The concept of rivers and lakes dedicated principally to service as carriers of the liquid wastes from industrial and urban metabolism is inherently revolting to the people. The citizen has to have water he can drink. He also wants beautiful rivers and lakes as well as paper, steel, gasoline, and polyethylene, and he is prepared to place a high price on the great natural assets of his land.

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USPHS TRAINING COURSES

The Public Health Service is offering a series of training courses at the Western Massachusetts Public Health Center on the Campus of the University of Massachusetts during the period of July 20–August 14. These courses are made possible by cooperative efforts of the U. S. Public Health Service, the University of Massachusetts, and the Massachusetts Department of Public Health.

The courses and outlines are as follows:

July 20–31	Basic Radiological Health
July 27–Aug. 7	Water Pollution Biology for Engineers
Aug. 3–14	Atmospheric and Source Sampling
Aug. 10–14	Bio-Assay of Pollution Ecology

Applications and further information may be obtained from Sylvan C. Martin, Regional Engineer, Region II, Public Health Service, 42 Broadway, New York 4, N. Y.

Stream Pollution

ADSORPTION OF ABS ON PARTICULATE MATERIALS IN WATER

By Charles E. Renn and Mary F. Barada

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For 15 months exploratory studies have been carried on to determine the fate of alkyl benzene sulfonate in natural water systems and in early stages of domestic water treatment. The studies were principally concerned with the residue of alkyl benzene sulfonate that passes through waste treatment or which reaches streams in untreated wastes. For all practical purposes, it may be said that all major surface waters receive varying quantities of ABS and other synthetic detergent principals. In only a few special cases, essentially representing drought disaster conditions, have concentrations developed which produce foam or interfere with flocculation in water treatment. It is significant that the conditions under which the concentrations of synthetic detergent rise to these levels also introduce other serious problems due to the associated gross sewage pollution of the water source.

Heavy reliance is placed on the processes of natural self-purification of surface waters in developing domestic water supplies from surface sources. It is inevitable that the waters of larger rivers and lakes shall be reused a number of times in their courses or during their long replacement cycles. A substantial science has been developed to define the balance of equities in surface water resources use.

The very marked activity of ABS led to this examination of its adsorption from dilute water solutions on soil, silt, and other fine suspended solids. This part of the self-purification potential of natural waters is seldom assessed, though it is generally recognized that substantial concentrations of organic pollutants are removed from water in the early stages of treatment through the simple expedient of removing the suspended solids load. This is done by settling in raw water storage or by combined flocculation and settling.

The limitations of the analytical methods used in earlier studies made it necessary to examine the uptake of alkyl benzene sulfonate in systems where concentrations of the alkyl benzene sulfonate and of the suspended materials were much higher than those commonly occurring in waste-bearing surface waters used for water supply. The present studies are aimed at obtaining a clear comparison of the various natural adsorption systems.

Soil Adsorption

With the object of determining whether soils would bind alkyl benzene sulfonate, 1,500 ml of a 5-ppm ABS solution were dripped through a 300-g column of fertile garden soil and the extract was analyzed for ABS at intervals during the irrigation. After the soil void volume has been exchanged about 30 times substantially all of the ABS could be recovered; the soil column was completely saturated. After only five exchanges approxi-

TABLE I.—Adsorption of ABS in Irrigated Soil Column Containing 300 g Dry Weight

Item	Concentration (ppm)
ABS in irrigant water	5
ABS in effluent*	1.9–2.17
ABS in effluent†	4.8–4.8

* After irrigation with 250 g test water.
† After irrigation with 1,500 g test water.

mately 40 per cent of the ABS appeared in the effluent. At the assumed saturation level this specimen of garden soil adsorbed 0.00137 per cent of its weight as ABS. The test soil was a humus-rich, loamy soil, slightly alkaline, and free of sand and fine gravel.

The ABS uptake of the same soil in suspension was, as would be anticipated, substantially less efficient than that observed in the irrigated column. When a thick mud slurry was prepared from 300 g of the soil in a 5-ppm ABS solution, the supernatant from the settled mixture bore approximately 90 per cent of the original ABS concentration. Less than 10 per cent was taken up by the soil. When the ABS solution was brought in contact with the soil by this method, the weight ratio of ABS adsorbed to soil was less than one part in 100,000. This first experience is set out in Table I.

Natural Stream Silts

An examination of natural stream silts was made next. Water samples were taken from three local streams following heavy rain and were settled for 30 min to bring down heavy materials. The supernatant was enriched with ABS to bring the system to 2.5 ppm ABS. The waters were then run through analytical filter membranes * and the residual ABS in the filtrate determined.

In this study a substantially higher ratio of ABS adsorbed to mass of suspended material was found, from approximately 1.9 to 3.8 per cent. At this high concentration of ABS, from 26 to 52 lb of dry silt solids were required to adsorb 1 lb of ABS. Table II describes this experiment. Removing the silt from the water containing 2.5 ppm ABS decreased the ABS concentration from 8 to 15 per cent. The removal of ABS by mechanical clarification of such waters obviously has limited value as a practical device. It is notable, however, that the fine natural silts from the stream samples were much more efficient (and under less favorable conditions of concentration) than the soil. Roughly 50 tons of soil would be required to bind 1 lb of ABS in the 5-per cent mud system at twice the initial ABS concentration.

Hydrophilic and Hydrophobic Substances

It is obvious that much effort and time could be spent in descriptive studies of ABS adsorption on a great variety of water-borne fine materials from many waters. It was felt that a more general approach could be made

* Millipore Filter Corporation, Watertown, Mass.

TABLE II.—Removal of ABS from Water by Silt Adsorption

Test No.	ABS in Silted Waters (ppm)	Silt in Test Waters* (ppm)	ABS Recovered in Clarified Waters (ppm)	ABS Removed per ppm Silt Removed (ppm)	Weight of Silt (dry) Required to Remove 1 lb ABS (lb)
1	2.5	17.5	2.16–2.16	0.0194	52
2	2.5	5.0	2.37–2.37	0.0260	38
3	2.5	5.0	2.30–2.32	0.0380	26

* Representing total dry solids in local streams, sampled during winter flooding, and allowed to stand for 30 min to remove heavy, settleable solids. These tests were taken to indicate behavior of fine silts that commonly escape settling basins.

TABLE III.—Removal of ABS from Water by Adsorption on China Clay*

ABS From Various Sample Points	Concentration (ppm)
In test clay-bearing water	5
In filtrate from 400 ppm clay suspension	4.30–4.33
In filtrate from 800 ppm clay suspension	4.04–4.04
In filtrate from 2,000 ppm clay suspension	3.27–3.27

* Mass China clay required to adsorb 1 lb ABS = 573 to 1,155 lb.

by observing the adsorption characteristics of ABS on two broad classes of surfaces; those that are readily wetted by water and those which are not readily wetted by water but which have an affinity for hydrocarbons. Therefore, a relatively short study of the adsorption efficiencies of ABS in suspensions of known hydrophilic and of hydrophobic particles was made for the purpose of identifying the parts of natural purification processes and of water treatment techniques that might be most profitably explored.

This preliminary study showed that materials that adsorb the hydrocarbon branches of ABS are markedly more effective in taking ABS from water solution than those that attach to the water-seeking bond. Petroleum oil emulsions, powdered paraffin, and activated carbon were used to represent the first class of adsorbents. China clay, talc, diatomite, silica gel, and precipitated calcium carbonate were used to represent the second. This finding was anticipated but the experimental work was carried out to verify the prediction and to develop rough values for the relative effectiveness of these materials.

China Clay

When suspensions of China clay, made up in 5-ppm ABS solution to levels of 400, 800, and 2,000 ppm dry clay by weight, are mixed and brought together, the filtered supernatants from the settled systems show that the efficiency of the clay falls in the range of efficiency for the natural stream silt. As Table III demonstrates, the higher concentrations of clay adsorb higher ABS loadings but the ratio of ABS adsorbed to China clay in the system varies in the opposite direction. One pound of ABS is taken up by from 573 to 1,155 lb of clay. These results tend to indicate simple surface adsorption.

Talc, Diatomite, and Silica Gel

The loading of ABS adsorbed from 5-ppm ABS solutions by 1,000-ppm suspensions of talc, diatomite, and silica gel is in the same range as that taken up by 800 ppm China clay. The behavior of the last two materials in this experiment should be of some interest to sanitary engineers for the following reasons: (a) diatomite is used in a variety of small filters and there is interest in its application to larger supplies, and (b) a variety of silicates is used in clarification and color removal and in special taste and odor control techniques.

Talc, which wets less strongly with water than either diatomite or silica gel, takes up a higher ABS loading than diatomite or silica gel. This is shown in Tables IV and V. Under comparable conditions, 1 lb of ABS is taken up by 363 lb of talc, by 1,490 lb of diatomite, and by 1,530 lb of silica gel.

Precipitated calcium carbonate has ABS-capturing properties slightly lower than that of the natural silt previously checked; 1 lb of ABS is captured

TABLE IV.—Adsorption of ABS on Talc and on Diatomite

ABS from Various Sample Points	Concentration (ppm)
In test waters	5
In filtrate from 1,000 ppm talc suspension	2.28–2.28
In filtrate from diatomite suspension	4.33–4.33

TABLE V.—Adsorption of ABS on Silica Gel in Water Suspension

ABS from Various Sampling Points	Concentration (ppm)
In test waters	5
In filtrate from 25 ppm silica gel suspension	5.0–5.0
In filtrate from 50 ppm silica gel in suspension	5.0–5.0
In filtrate from 100 ppm silica gel suspension	4.82–4.82
In filtrate from 200 ppm silica gel suspension	4.59–4.65
In filtrate from 1,000 ppm silica gel suspension	4.35–4.35

on 300 to 1,000 lb of solids. The basic data are shown in Table VI.

Paraffin and Mineral Oil

Attempts were made to examine the uptake of ABS on powdered and granulated paraffin and these were inconclusive. Paraffin dust of satisfactory uniformity appeared impossible to achieve and attempts to get good suspensions failed. The data of Table VII reflect this. Only the 0.5- and 1-per cent suspensions of granulated paraffin showed measurable uptake of ABS and the calculated effectiveness was low. It is evident that the necessary surface area was not obtained, particularly when the results of this test are compared with the performance of a much more dilute emulsion of mineral oil (Table VIII). In the mineral oil experiment it should be noted that the loading of ABS per unit of oil in the emulsion follows the pattern of adsorption; the highest efficiencies occur with the lower concentration of adsorbent. The oil emulsion sweeps out 1 lb of ABS with each 26 to 194 lb of oil.

TABLE VI.—Adsorption of ABS on Fine Calcium Carbonate

ABS from Various Sampling Points	Concentration (ppm)
In test waters	5
Recovered from supernatant of 10 ppm calcium carbonate suspension	4.80–5.0
Recovered from supernatant of 50 ppm calcium carbonate suspension	4.65–4.85
Recovered from supernatant of 100 ppm calcium carbonate suspension	4.65–4.85
Recovered from supernatant of 250 ppm calcium carbonate suspension	4.45–4.48

TABLE VII.—Adsorption of ABS on Granulated Paraffin*

ABS from Various Sampling Points	Concentration (ppm)
In test waters	5
In water phase of 1,000 ppm paraffin suspension	5.0–5.0
In water phase of 2,000 ppm paraffin suspension	5.0–5.0
In water phase of 5,000 ppm paraffin suspension	4.84–4.90
In water phase of 10,000 ppm paraffin suspension	4.30–4.30

* Mass of granulated paraffin required to remove 1 lb of ABS = 14,000 lb.

TABLE VIII.—Adsorption of ABS on Mineral Oil Emulsion*

ABS from Various Sampling Points	Concentration (ppm)
In test waters	5
In water phase of 10 ppm mineral oil emulsion	4.58–4.62
In water phase of 20 ppm mineral oil emulsion	4.38–4.58
In water phase of 40 ppm mineral oil emulsion	4.30–4.30
In water phase of 80 ppm mineral oil emulsion	4.30–4.30
In water phase of 200 ppm mineral oil emulsion	3.97–3.97

* Mass of oil required to remove 1 lb ABS by emulsion extraction = 26 to 194 lb.

Activated Carbon

The efficiency of ABS removal by activated carbon is being studied in much greater detail than was the removal efficiency of other substances. Preliminary studies by the authors and others indicated that activated carbon treatment of waste-bearing waters is likely to be the method of choice for

efficient removal of ABS should this step become necessary. More sensitive methods have been adapted for measuring low concentrations of ABS so that data are being developed on the performance of activated carbon in the practical ranges that occasionally occur in heavily polluted surface waters that must be used for municipal supplies.

The effectiveness of ABS removal by a water treatment grade of carbon in the range of 0.2 to 2.0 ppm has been explored. The lowest concentration represents peak ABS values for heavily polluted rivers; the highest falls in the range of treated sewage effluent. The adsorption of ABS follows the classical adsorption pattern on activated carbon that is common to color- and odor-producing substances. Higher concentrations of carbon remove larger quantities of ABS but the mass of ABS per unit of carbon rises as the carbon dose declines. In other words, the unit efficiency of activated carbon increases as the concentration of ABS increases.

The analytical technique used in these studies for low concentrations of ABS * has not permitted close definition of the characteristics of an ABS-activated carbon system. It has, however, been adequate for making rough estimates of carbon requirements for removing 50 and 90 per cent of ABS at varying detergent concentrations.

Table IX summarizes the findings from a number of activated carbon experiments. These indicate that substantial concentrations of carbon are required to reduce ABS loadings of heavily polluted or reused waters. They also show that it is possible to reduce drastically high ABS concentrations with activated carbon and that there is a method for eliminating unacceptable peak loads of this component in detergent-bearing water sources.

* A modification of the methylene blue method used by Procter and Gamble Company's control laboratories.

TABLE IX.—Summary of Tests for Determination of Activated Carbon Requirement for Removing Alkyl Benzene Sulfonate from Water Solution

Initial ABS Concentration (ppm)	Carbon Requirement for Different Degrees of ABS Removal		Carbon Loading (lb/lb ABS)
	50% Removal (ppm)	90% Removal (ppm)	
0.2	12	40	120–220
0.5	18	60	72–120
1.0	25	80	50–89
2.0	40	95	40–53

Fine-Bubble Aeration

It may be desirable to mention at this point that promising results have been obtained from experiments with fine-bubble aeration combined with activated carbon removal. This introduces the application of a somewhat unorthodox technique to water treatment but it is of value because it provides a useful and simple method for reducing very high ABS concentrations to levels where other methods, such as activated carbon adsorption, may be applied economically. This is a device which the authors feel has great possibilities for treating wastewaters for industrial reuse.

Acknowledgment

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THE OPERATOR'S CORNER

TELEVISION FOR SEWER INSPECTION *

By Arthur D. Caster

Principal Sewage Disposal Engineer, Cincinnati, Ohio

Since the beginning of time man in his many day-to-day activities has accepted the fact that his sense of seeing is limited by two basic considerations. First, there must be a source of visible light to illuminate the object or scene which he desires to observe, and, of equal importance, a direct line-of-sight path must exist between the scene or object and the eyes of the observer. The first of these restrictions has become negligible since the advent of practical and efficient sources of artificial light. The second, which may be thought of as the problem of bending light around obstructions in its normal path, has been dealt with by such optical devices as periscopes and mirror systems, all of which have been ineffectual except for short distances and limited fields of view.

Then came television, and in a few short years the centuries old problem of "seeing where you can't look" has been solved. It is an interesting fact that, at first, the solution did not appear to be a practical one for industrial purposes because of the high cost and complexity of the equipment involved. However, this initial obstacle was resolved by the development of simplified tubes and circuits, with the result that, almost overnight, industry, education, and commerce have been presented with a new tool having hundreds of possibilities for performing tasks previously thought impossible, or in accomplishing existing work more economically.

The executive or engineer not familiar with television, but desiring information regarding the possibilities of applying television to his own plant, school, or office, soon discovers that the data needed to plan a practical working system can only be found by diligently searching through trade periodicals, engineering reports, and the sales literature of the manufacturers of industrial television equipment, coaxial cables, lighting equipment, and various accessories usually needed to complete a practical working system. The basic principles of industrial television equipment are essentially those of television broadcasting, except that the broadcasting television transmitter is replaced by a direct metallic connection with the receiver. Thus, the term, "closed-circuit television," frequently is used to describe such systems. Another very important difference between the two systems is the much greater simplicity of the industrial television camera and its accessories. In fact, it is the simplicity and convenience which are the major factors responsible for its many present and potential applications in industry,

* Presented at the 32nd Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conf.; Toledo, Ohio; June 18–20, 1958.

education, and commerce. Standardization facilitates the initial installation of a basic system, permitting easy expansion as the necessity occurs. In most situations, nothing need be discarded or replaced. It should also be noted that specially trained operators are not required for the normal operation of closed-circuit television equipment. When the equipment is permanently mounted for continuous observation of the same process or area, operating adjustments are seldom necessary; if required, they can be made easily either at the camera location itself or from a distant "remote control" point. Even changes in light intensity on the work scene are automatically compensated for by some equipment.

Cincinnati's Use of TV

In Cincinnati closed-circuit television is used for the following purposes.

1. Inspection of regulators, interceptors, and manholes in the sewage collection system. Depths vary from 20 to 75 ft. See Figures 1, 2, and 3.

2. Inspection of chambers. All chambers are constructed without manhole steps. Access to these chambers is by rope ladder. With the use of the television unit, inspection can be made from ground level. Since grease fittings are extended from the regulators and valves to the ground level all routine service can be done without entering the chamber. When inspection reveals that repairs are necessary a report is made and a maintenance crew takes over.

3. Tunnel inspections during construction.

4. Inspection of appurtenances under water by lowering camera and lights into the water. Inspection of outlets for interceptor sewers to the river may thus be inspected and studied.

FIGURE 1.—Television camera in large, brick sewer. Notice crack in crown.

FIGURE 2.—The TV camera in Figure 1 saw this crack in the brick sewer.

5. Inspection of equipment in confined places. This application is especially valuable for training and public relations work. Understanding the operation of confined units, such as rabble arms in incinerators, the crank shaft of a diesel engine, etc., can be greatly enhanced by observing the actual operation.

6. Inspection of material being tested in the laboratory. Here the unit can be placed in extremely high or low temperature, or where special gases such as ammonia or chlorine are being used.

In addition, photographs can be taken of the monitor screen to make permanent records (Figures 2 and 3).

Television Equipment

Trailer

The television equipment is housed in a one-ton, two-wheel cargo trailer (Figure 4). Two combinations of running lights and caution lights are installed. These are powered by the towing vehicle. The wheels are equipped with brakes which are operated by a hand lever located on the right side of the trailer near the rear of the body. These brakes are used for parking purposes only. Special ratchet-type supports are installed at each corner of the trailer bed for use in leveling and securing the trailer bed in a firm position. The ratchets are operated by individual hand cranks. An aluminum frame projects above the trailer sides upon which a specially made canvas duck cover is attached. This cover opens at both ends with zippers. On this aluminum frame a 300 w, 110 v spotlight is mounted for lighting the working area of the trailer bed.

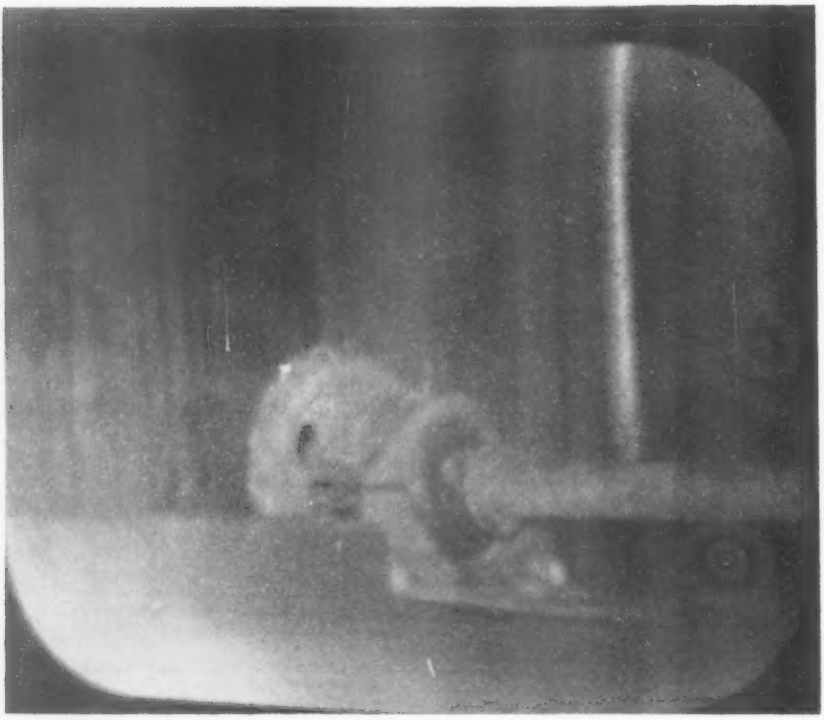

FIGURE 3.—This is what the inspection crew saw on the monitor screen after lowering the TV camera 40 ft below the surface to check on the condition of the chain and pillar box in a regulating chamber.

Power Source

Installed in the front end of the trailer is a gasoline-driven power plant,* with 2,000 w a-c capacity. It maintains 115 v, 60 cycle, single phase, with a full load capacity 17.4 a at 3,600 rpm.

Television System

The television pickup system † consists of two units, the camera head and the camera control unit.

The camera is 9 in. long, 3¼ in. wide, and 3½ in. high. It weighs 3½ lb.

The control unit is 13⅞ in. long, 19 in. wide, and 5¼ in. high. It weighs 30 lb. Housing for camera is made of bronze tubing 8 in. in diameter by 18¼ in. long. The entire case is chrome plated. The front end of the unit has a plexiglass window which is rubber sealed and moisture proof. The rear end of the unit has a removable plate with handle, and is moisture protected by two "O" rings. A watertight fitting is installed in the top of the case through which the coaxial cable of 24 leads passes. A support frame is brazed on top of the case for

* Fairbanks-Morse Model 20PX—36,, Series A-342.

† The entire unit was designed and manufactured by the Diamond Power Specialty Corp., Lancaster, Ohio, from basic designs of the author and his associates.

support, and control of direction. See Figure 5. The cable from the camera to the control unit is 125 ft long.

The picture monitor is a high quality unit especially designed for industrial television systems. It is designed to produce a clear, bright, high definition picture under conditions of average indoor illumination. On the front panel are an off-and-on switch and controls for contrast, brightness, vertical linearity, height, and vertical and horizontal hold. Secondary controls are horizontal frequency, horizontal linearity, width, horizontal drive, and focus. The control unit and monitor are installed in a frame which is installed on rubber shock mounts.

The units, camera, control, and monitor are all grounded back to the power generator. In addition arrangements have been made so that external power can be used on the trailer instead of the power generator. Two

FIGURE 4.—Cincinnati's mobile television unit.

FIGURE 5.—Close-up of turntable and television camera.

150-w flood lamps are attached to the pole support for illumination purposes. The power to these lamps is supplied through the coaxial cable.

A specially designed handling mechanism is used to control the camera. This unit consists of a portable frame, which runs on tracks and can be pulled back over the tail gate of the trailer. This mechanism consists of a turntable, a motor-driven cable winch, and portable aluminum pole sections, which control the direction of the camera (Figures 5 and 6). By operation of a control switch the camera can be raised or lowered. By rotation of the turntables the camera can be rotated 360 degrees. A limit switch is installed to prevent running out of the pole support. The connecting cables allow working approximately 1,000 ft away from the monitor. A portable unit for use in areas where the trailer cannot be taken has been built by the sewage disposal section.

Cost

The cost of the component parts is given below:

Item	Cost
Surplus Army cargo trailer	$ 50.00
Camera, complete with mounting and monitor	3,673.50
Raising and lowering mechanism, trailer-mounted	3,500.00
Total	$7,223.50

It is estimated that the labor saved in two years will equal the investment cost. The safety advantages inherent in a ground-level inspection program cannot be measured.

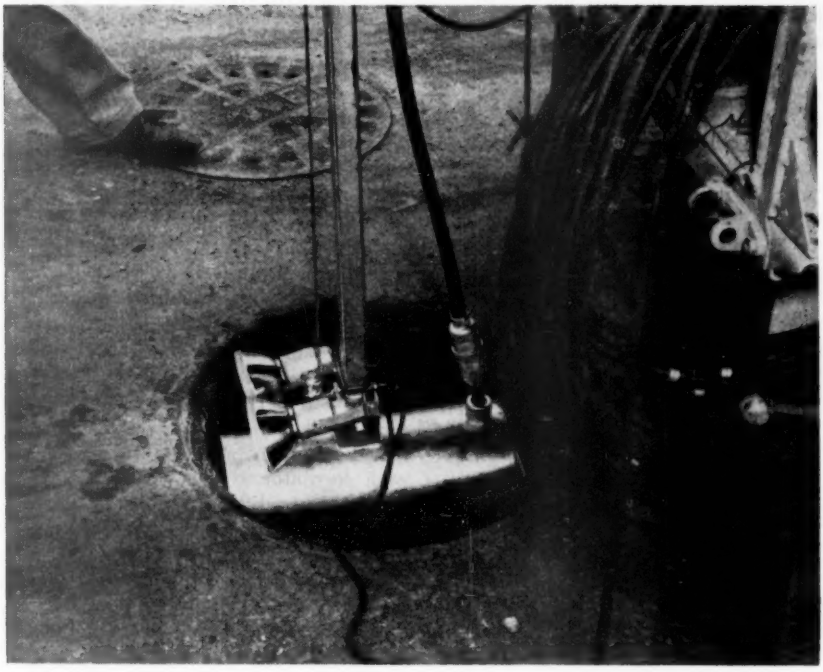

FIGURE 6.—Camera being lowered into manhole.

Acknowledgment

Special appreciation goes to Leo Krapp and Ott Lindeman of the Maintenance Department of Sewage Disposal for their work on this project and assistance in the preparation of this description.

MAINTENANCE OF STORM FLOW REGULATORS *

By Max B. Phillips

Superintendent, Sewage Treatment Works, Bryan, Ohio

During storm periods and thaws, excessive flow volumes in combined sewers and sometimes in sanitary sewers, may cause considerable damage or serious inconvenience if not relieved at desirable points. Thus some type of regulator for flow control must be installed on the system. Generally, these regulators are placed on combined sewers near an available outlet to a watercourse and are designed to limit the flow which will reach the sewage treatment works. Usually, flows from 50 to 200 per cent above the dry weather flow are admitted to the interceptor. As a matter of fact, where the sewerage system terminates at a treatment works,

* Presented at the Annual Meeting, Ohio Sewage and Industrial Waste Treatment Conf.; Toledo, Ohio; June 18–20, 1958.

flows only 25 to 75 per cent above the nominal plant capacity can be fully treated. If greater volumes are received, a portion must be bypassed or only partially treated.

When regulators fail to perform satisfactorily and sewage escapes to a watercourse at other than permissible times a serious pollution problem may be created.

Regulator Use in Ohio

To obtain a broad, clear picture of the use and performance of regulators in Ohio, questionnaires were sent to 60 municipalities of which 43 responded. Of these, 33 have regulators. The number varies from 2 reported in Salem to the complex of 378 regulators in Cleveland. Thirty per cent of the municipalities listed regulators as a major problem; 51 per cent reported some difficulty with regulators; and 18 per cent reported little or no trouble.

Types of regulators used are noted in order of decreasing frequency: overflow dams or weirs; flood gates; orifices; float-operated gates; and leaping weirs. Malfunctioning, at times, was reported for all types. The causes of malfunctioning that were reported included corrosion, accumulations of grease, and foreign objects. Some difficulties were attributed to poor design and adjustment. Flood gates have been a wide-spread problem at Middletown and Lancaster.

Regulator Inspection

In the municipalities reporting, about half of the regulator systems are inspected by sewage treatment plant personnel; the remainder by street departments or departments of public service. It is apparent that among the villages and small- to medium-size cities, regulator inspection is carried out mainly by treatment plant personnel. In the larger cities it has been necessary to place the responsibility with the departments of public service or an allied department because of the large size of the system. The frequency of inspection ranged from daily to quarterly.

It was interesting to note that in only 20 per cent of the municipalities were treatment plant personnel responsible for regulator maintenance.

Bryan's Maintenance Program

In Bryan, regulators have been a continuous problem. In the interceptor constructed during 1938–39, 50 orifice-type intercepting manholes were built. Some were proposed as temporary, while others were to be permanent. Further sewer construction has eliminated only four of these regulators.

The location and identification of each regulator are shown on a report form. Inspections are made on Monday and Friday mornings by plant personnel and the condition of each regulator is noted. By analyzing these records the optimum orifice-size for each manhole can be selected. Since all regulators are on combined sewers, the stoppages are usually caused by street washings or large objects that lodge in or near the orifice and collect solids. Normally, only a long pole is required to open these orifices and the collection of debris and sludge is washed into the intercepting sewer.

Occasionally, additional maintenance may be required. In these cases a work request is sent to the street commissioner who sees that the job is done. He, in turn, reports back to the plant on the cost of work performed.

When pressed for time, regulators which have a poor performance history are inspected first. Regulators also are inspected after a rainstorm or thaw.

Conclusions

In general, it is believed a workable program of regulator inspection and maintenance can be developed from the following outline:

1. Determine the extent of the problem.

2. Provide the proper information to the governing body.

3. Determine the responsibility for inspection and maintenance.

4. Determine the frequency of inspection.

5. Provide the necessary tools and equipment, including record forms and safety devices.

6. Have a fairly flexible program and make changes and adjustments whenever necessary.

7. Include the cost of inspection and maintenance of the regulator system as a budget item, and make frequent reports to the governing body.

It is the writer's opinion that sewage treatment plant officials should have control of the regulator system. If this is not possible, all records of inspections and maintenance should be made available to the plant.

Actual maintenance is probably better carried out by the street or allied departments inasmuch as they usually have the necessary equipment and engage in similar activities on a full-time basis.

Records of regulator performance are just as important as the records kept on bypassing at sewage treatment plants.

GENERAL PRINCIPLES OF CHEMICAL COAGULATION *

By M. C. Rand

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It is the objective of this paper to bring together certain aspects of our existing knowledge which are pertinent to the chemical coagulation of sewage. No new experimental data will be presented; neither is there any pretense of reviewing here all of the rather extensive and sometimes very sophisticated publications on the subject. The questions to be considered are the objectives of chemical coagulation as applied to the treatment of sewage and industrial wastes, the techniques available for realizing those objectives, their chemical and physical basis, to the extent that these are known, and the variables which influence the final results. It is hoped that this discussion will provide a general background for persons not already familiar with the chemical coagulation process, and perhaps also as a review for those already acquainted with the topic.

* Presented at the 44th Annual Meeting, New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J.; Mar. 11–13, 1959.

Objectives of Coagulation

The ultimate purpose of chemical coagulation of sewage or waste is the removal of particulate matter which cannot be separated from the liquid by gravity alone, either because it is too finely divided, or because its density differs too little from that of the suspending liquid. The means by which this result is accomplished is to collect these fine particles into aggregates of larger size, and possibly of a different density, which may then be susceptible to gravitational separation. If the process is successfully operated, there should result a degree of purification higher than that achieved by flotation or plain sedimentation, but not so high as that usually resulting from a biological treatment process. For this reason, chemical coagulation is sometimes termed "intermediate treatment." With strictly domestic sewage, normally the reduction of suspended solids ranges from 70 to 90 per cent, and the reduction of BOD ranges be-

tween 50 and 85 per cent (1). When dealing with industrial sewages, the results may or may not fall within the ranges stated, depending upon the composition of the sewage.

The applications of chemical treatment reflect the degree of purification the process can produce. Thus, coagulation is indicated for situations in which the effluent quality produced by primary treatment is not acceptable, but the quality requirements do not justify the added expense of secondary treatment.

Theoretical Considerations

Particle Size

Since the chemical treatment process is concerned primarily with the removal of fine particulate matter, the main body of theoretical information deals with the behavior of such nonsettleable particles.

The solids in sewage and wastes constitute a state of matter termed a dispersed system, which is a general name for a system in which one substance is divided into particles and distributed throughout a second substance. The particles in such a system are termed "dispersoids," and the suspending gas, liquid, or solid is the "dispersing medium." The particles, or dispersoids, may vary in size over a wide range, from small molecules or ions upward. Some authorities prefer not to apply these terms to systems in which the dispersed particles are large enough to be visible, with or without the use of magnifying devices, but for the present purpose it will be more convenient to cover all the particulate matter in sewage with one set of terms.

Colloidal State

Dispersed systems are subdivided on the basis of the size of the dispersed particles. If the particles separate from the dispersing medium under the influence of gravity when the system is held quiescent, the system is a suspension. This term then applies to relatively large particles. At the other extreme, dispersed particles consisting of small, simple molecules or ions constitute a solution. Between these two, there lies a range of intermediate particle sizes which is termed "colloidal." The size limits which separate colloids from true solutions and from suspensions are rather indefinite. Originally, the colloidal state was recognized on the basis of the behavior of the system, but the behavior does not change abruptly as the particle size passes a certain limit. Rather there is a progressive change of properties from coarse suspended matter through the colloidal size range to true solutions. Therefore, establishing limiting particle sizes to define the colloidal state is somewhat arbitrary. As a result, there are no limiting values which can be stated as the correct ones, but most authorities set the lower limit at about 1 mμ (1 mμ = 1 millimicron = one millionth of a millimeter). Likewise, the upper limit is usually set at about 1 μ (1 μ = 1 micron = one thousandth of a millimeter) (2).

Interest in the colloidal state stems from the fact that the solids affected by chemical coagulation are primarily those which exhibit the properties of colloids. The solids which are not removed by flotation or plain sedimentation range in size up to 100 μ (one tenth of a millimeter) (3). Even the largest of these, however, exhibit certain colloidal properties at least in some degree. It seems quite proper, therefore, to consider these larger particles with the colloids, and for the purposes of this discussion they may be considered as being colloids. An understanding of the behavior of dispersed systems in general, and of colloids in particular, is therefore helpful in understanding the process of chemical coagulation.

Stability of Colloidal System

Undoubtedly the most significant property of colloidal systems, from the

waste treatment standpoint, is the fact that colloids are not separated by the force of gravity alone. This characteristic is the perceptible end result of certain more subtle features of their behavior, which in turn are caused by the small size and mass, and the large surface area of the particles.

The small size and mass of colloidal particles contribute directly to the stability of colloidal systems since particles in this range are significantly displaced by collision with a molecule. Inasmuch as each particle is surrounded by molecules in constant motion, collisions occur frequently and result in continuous random movement of the colloid particles. Largely because of this effect and the relatively small force exerted by gravity on such minute particles, their movement in response to gravity is not significantly more probable than motion in any other direction. In other words, the effect of gravity is "overcome" by the random motion (Brownian motion) of the particles.

On the other hand, this Brownian motion tends to bring about frequent collisions between the colloid particles themselves, and if conditions are such that the particles come into actual contact and adhere, Brownian motion aids their growth into settleable aggregates.

Surface Area of Colloids

The fact that colloidal systems usually do not coagulate spontaneously as a result of Brownian movement is due primarily to effects resulting from the large surface areas which the particles present to the solvent. In fact much of the difference between dispersed systems and other states of matter is due to the tremendous area of the exposed surface of the dispersed phase. The magnitude of this factor becomes apparent if we consider a 1-cm cube of material, having a total surface area of 6 sq cm. If this cube is cut into eight cubes, each with edges 0.5 cm in length, the surface area is increased to 12 sq cm. If the material is further subdivided into cubes with 1-mm edges, there will result 1,000 particles, with a total surface area of 60 sq cm. Proceeding to the upper size limit of the non-settleable solids of sewage, if 1 cc of material is divided into cubes 0.1 mm on each edge, it produces one million particles, and the total exposed surface area is 600 sq cm. At the upper limit of the generally accepted colloidal range (1-μ particles), the original 1 cc produces one trillion (10^{12}) particles, with a total surface area of 60,000 sq cm, or 6 sq m. And finally, at the lower size limit of the colloidal range (particles 1 mμ in diameter), 1 cc of solid becomes 10^{21} particles, and the exposed surface area is increased to 6,000 sq m or about one and a half acres. Obviously, surface effects, which are not detectable on the cube having a surface area of 6 sq cm may become very pronounced when the material is dispersed to give a total surface area measured in square meters or acres.

Electrical Charge on Particles

One surface effect which is of great importance in determining the stability of colloidal systems is the fact that colloid surfaces tend to accumulate a definite electrical charge. For certain colloids of well-defined chemical composition, such as inorganic salts and purified proteins, a rather complex theory has been developed which relates the sign and the magnitude of the surface charge under given conditions to the composition of the colloidal particles (4) (5). This theory has been successfully applied in explaining the removal of certain inorganic ions from water by chemical coagulation (6) (7). There has been some disagreement among authors as to whether this effect should be attributed to adsorption of ions from the solution or to ionization of the surface of the colloid particle (6). However, both approaches as-

sume that the colloid surface contains polar groups. In sewage, a significant part of the non-settleable material consists of non-polar compounds, such as carbohydrates and esters (8). Even for these substances, it is to be expected that the surfaces of colloidal particles will accumulate a charge since apparently any solid, regardless of its composition, when in contact with a gas or a solution, tends to adsorb on its surface a layer of gas molecules or dissolved molecules or ions. This effect is relatively minor with massive solids, but as has been shown, the surface areas of colloidal particles are enormous compared with their mass. The affinity of a given solid ordinarily differs for any two different kinds of solute particles. In any aqueous system ions are invariably present—hydrogen and hydroxyl ions even if all others are absent. Colloid surfaces then adsorb these ions, and usually in unequal quantities. It is safe to generalize, therefore, that all the colloids of sewage usually carry electrical charges.

These charges contribute importantly to the stability of the colloids. The simplest way of considering their effect is merely to state that all the colloid particles of the same kind carry a similar charge, and therefore repel each other. The repulsion decreases the probability that the particles will collide and aggregate into clumps of settleable size. The more complete theory explains the quantitative features of this effect on the basis of the composition of the colloids and of the surrounding medium (4). For discussion purposes, however, it is sufficient to note that the successful coagulation of these fine particles is greatly aided by the neutralization of these charges. In practice, this is best accomplished by reaction with either ions or colloids bearing charges opposite in sign to the charges on the colloids to be removed.

Sewage Colloids

The composition of the organic matter of domestic sewage is such that the majority of the colloids are negatively charged unless free mineral acidity is present. They are therefore neutralized primarily by reaction with the cations (positively charged ions) of added electrolytes. In general, cations of higher valence are more effective. No strict quantitative relationship between valence and effect has been described, but the trend is well marked and well known. Thus, trivalent ions such as aluminum and ferric ions are in general more effective than divalent ions, e.g., calcium and magnesium, which in turn have much greater effect than monovalent cations. Typical reports show that trivalent ions are five or ten times as effective as divalent, and several hundred times as effective as monovalent ions.

Also, when dealing with domestic sewage it is usually found that the best results are accomplished by coagulation in the slightly acid range, presumably because under these conditions the inorganic floc produced by hydrolysis of the coagulants bears positive charges.

Another surface effect important to colloid stability is the hydration of the particles. When the chemical nature of the colloid is such that it has a strong affinity for the molecules of the solvent, the colloid is termed "lyophilic." In such cases, each particle is solvated. In other words, a layer of solvent is closely bound to the surface of each particle. This "shell" of solvent is believed to offer mechanical resistance to coagulation (6), probably by tending to prevent contact between the particles themselves.

A similar but distinct case may occur with colloid particles which, due to their composition, do not have a high affinity for the solvent. If another substance is present having affinity for both the dispersed and the dispersing phase, the stability of the system is

greatly increased. The most familiar example of this effect is the emulsification of oil in water by soap. Systems of this type have been termed protected colloids, and the stabilizing substance the emulsifier or the protecting agent. Apparently in these systems the colloid particles are surrounded by a solvent shell comparable to that of the lyophilic colloids.

In the coagulation of both lyophilic and protected colloids, the stabilizing effect of the solvent shell must be overcome. Unfortunately, little is known of means of accomplishing this end which can be generally applied in sewage treatment. Experimentally, desolvation is usually accomplished by adding high concentrations of salts or organic solvents to the system, but this approach offers little promise in the field of wastewater treatment.

In some cases, a change in the chemical composition of the colloid particles may result in a change of colloid-solvent affinity. For example, the partial coagulation sometimes produced by chlorination may be due to this effect. However, knowledge of the process is not complete enough to permit its intentional application. A somewhat parallel situation may occur with protected colloids. In these cases, a change of composition of the emulsifying agent may destroy the emulsion completely, as for example, if the soap stabilizing an emulsion of oil in water is precipitated by a calcium salt.

Applications to Practice

Basic Principles

Practical methods for the removal of non-settleable particles from sewage and wastes may be referred to two fundamental principles. The fine particles may be adsorbed on larger pre-existing particles, or the colloids themselves may be aggregated into particles of settleable size. Trickling filters, sand filters, and the activated sludge process accomplish colloid removal largely by the former process, followed by oxidative destruction of the organic constituents of the colloids. In chemical coagulation, however, both adsorption and aggregation are of importance.

In terms of plant operation coagulation consists normally of two steps. In the first, one or more chemicals are added to the sewage or waste and distributed as quickly and as uniformly as possible throughout the whole volume to be treated. This first step is referred to as mixing—often as flash mixing—to distinguish it from the following step. Although the principal objective of this step is solution and distribution of the chemicals, their reaction with the water, the colloids, and each other certainly begins immediately.

The second step is termed flocculation and consists of a longer period of more gentle agitation. During this phase the chemical reactions continue and are followed or accompanied by the physical reactions which result in coalescence of some of the non-settleable particles of the sewage into settleable aggregates.

Although a wide variety of techniques and equipment are available for use in these two steps, all are based upon the principles just outlined. Flocculation is normally followed by sedimentation or flotation, which however, are usually considered to be separate processes.

Coagulant Reactions

The chemicals most used as coagulants are salts of polyvalent, usually trivalent, metals. The reactions into which they enter in coagulation are complex and not fully understood. One reaction which is certainly important is the hydrolysis of the coagulant by the bicarbonate alkalinity present in the sewage or waste to produce an insoluble metal hydroxide. If this were the only reaction there should be a constant relationship between the amount of coagulant added, the amount of alkalinity consumed, and the amount

of carbon dioxide formed. However, the decrease of alkalinity and the release of carbon dioxide are always less than the theoretical amounts and the ratio of actual to theoretical values is not constant (9). This indicates that other reactions are involved. Usually the hydrolysis of the coagulant is incomplete and the floc contains anions other than hydroxide (10). Also, part of the cations of the coagulant may react directly with the sewage colloids. In such reactions, the difference between neutralization of the colloid charges and formation of salts of the colloids becomes rather indistinct if specific cases are considered. Certainly, however, a part of the coagulant is consumed in this way.

Within the first few seconds after the coagulant contacts the sewage or waste, the formation of insoluble reaction products results in the appearance of microscopic precipitated particles. At the same time, reaction of the coagulant with the colloids of the sewage has rendered them more susceptible to aggregation, primarily through reduction of their surface charges. During the flocculation period several processes take place simultaneously. The minute particles of precipitated hydroxides or basic salts produced from the coagulant increase in size as further precipitation occurs on their surfaces. If the concentration of coagulant exceeds the concentration of hydroxyl ion, as is usually the case, the particles maintain positive charges. Any negatively charged sewage colloids, therefore, tend to be attracted to the floc particles and adhere to them, further increasing the size of the floc. As the inorganic portion of the floc continues to grow by continued precipitation, the sewage colloid particles may be completely surrounded and enclosed in the interior of the floc. Meanwhile the colloids of the sewage or waste have been partially neutralized by reaction with the coagulant cations, decreasing their electrostatic repulsion. The gentle stirring provided as a part of the flocculation process causes frequent collisions among the various small particles present. The particles tend to cohere whenever they contact one another at this stage, so the over-all result of the reactions of the coagulant and the stirring of flocculation is relatively rapid growth of the size of the floc particles.

The degree of turbulence produced in the flocculation step is of great importance to the over-all results, as it greatly affects the maximum size of the floc particles produced. Some turbulence is essential to cause collision of the small particles and their growth into settleable aggregates, but on the other hand, violent turbulence tends to break up the floc. It is essential, therefore, to find the proper degree of stirring for best results.

Coagulants in Use

The chemicals employed in coagulation are often considered in two categories, the coagulants, and the coagulation aids. Those considered as coagulants are salts of polyvalent, usually trivalent, metallic ions. Those more commonly used include alum, ferric chloride, ferric sulfate, and chlorinated copperas. Experimentally, many other similar compounds are effective coagulants, for example titanium salts and aluminum chloride, but such practical considerations as their cost and availability prevent their use for sewage treatment except under unusual circumstances. The coagulants in general are chemicals capable of forming a floc and producing coagulation when they alone are added to sewage and waste under the proper conditions.

Coagulant aids, on the other hand, are chemicals which produce little or no floc formation when they are used alone, but which may improve over-all results obtained by the use of coagulants. In sewage and waste treatment their primary function is usually pH adjustment and of the chemicals used for this purpose, lime is by far the most

important. Sodium aluminate, activated silica, certain clays, and other materials are used in water treatment but they are seldom used in treating sewage and industrial wastes. The primary function of these products is to provide microscopic nuclei which serve as starting points for the growth of settleable floc. Since sewage already contains sufficient particulate matter, there is usually little advantage to be gained by their use. Synthetic organic poly-electrolytes are now being offered commercially for use as coagulant aids, but data regarding their use in full-scale treatment are still rather meager because of their newness.

Coagulant Selection

The choice among the various coagulants available is a problem which must be solved separately for each specific situation. It is usually necessary to determine experimentally the relative amounts of different coagulants needed to produce acceptable results, and to evaluate the experimental data in terms of the relative costs of the various alternatives. In this connection, the use of by-product materials, which may be unusually cheap or readily available at a particular plant, should not be overlooked.

In the majority of cases the choice will be made between alum and certain iron salts. As a class, the iron salts are in most locations more expensive than alum, and they have certain disadvantages in regard to ease of handling since they tend to be hygroscopic, corrosive, and rather slow to dissolve. On the other hand they are often better coagulants than alum. The pH for coagulation tends to be less critical when using iron salts than with alum, and the ferric ion generally appears to be more effective than the aluminum ion as a precipitant for negative colloids. The iron floc tends to be more dense and physically stronger, which improves settling and permits somewhat more vigorous agitation during flocculation. Finally, the iron salts quantitatively remove any sulfides which are present.

It should be emphasized, however, that these generalities can serve only as an indication as to which compound appears the most promising before experimentation is begun. It is quite possible, indeed quite likely, that in any given plant results may not hold with those obtained elsewhere.

Factors Affecting Coagulation

The variables which affect the final results form an impressive list, including the kind and amount of coagulant and of coagulant aid, if any, the amount and kind of suspended and colloidal matter present, the pH, the dissolved solids concentration, the acidity, alkalinity, and other chemical characteristics of the sewage, the time interval between additions of the various chemicals used, the order of their addition, the duration and the violence of the mixing provided for both distribution and flocculation, and the temperature. Fortunately, in solving any practical problem some of these factors are fixed, so that it is seldom necessary to determine the optimum values of all of them. For example, in almost all cases the various parameters relating to the composition of the sewage to be treated are beyond the control of the persons concerned with its treatment. Also, in dealing with an established plant the time and the turbulence provided for mixing and flocculation are usually fixed, or may be varied only within narrow limits. Thus, ordinarily the operator is concerned only with determining the kind and amount of coagulant and coagulant aid and the pH which give best results or which give the desired results most economically. When the problem is not the operation of an existing plant but the design of a new plant or plant additions, the effects of certain other factors may also need to be examined. For instance, it may be necessary to consider varying

the retention time and the rate of agitation in the mixing and flocculation steps. If more than one chemical is to be used, the order of their addition and the time interval between additions must also be determined.

Laboratory Evaluation

The details of a program of experimentation with coagulation are not within the scope of this discussion. However, certain general considerations may be worth mentioning. First, it is important to set up the conditions of laboratory experimentation so that they parallel plant conditions as nearly as possible. If the retention time in the mixing, flocculation, and sedimentation steps are fixed, corresponding time intervals should be used in the experiments. If variation is possible in the plant, then the various times tested in the laboratory should correspond to those available in actual operation. Likewise, the order of addition of chemicals and the time interval between additions should be based upon the plant design. Since so much depends upon the chemical characteristics of the sewage it is perhaps needless to say that the samples used in the laboratory should be representative of the material which will be treated.

In various accounts of experimental work along these lines, it is apparent that many different parameters have been used to evaluate the results of the various conditions tested. Among them have been the time required for the formation of visible floc, the amount of floc formed in a fixed length of time as judged either by visual observation or by weighing, the settling rate of the floc formed, the size of the floc, and the turbidity, either before or after sedimentation. It seems better to judge the success of the experiments in terms of the results which are expected on a plant scale. Usually, this means that the suspended solids reduction should be determined for each set of conditions being tested and if BOD removal is also one of the objectives of the treatment, this should also be determined.

Finally, it is emphasized that laboratory coagulation tests cannot replace, and should not be expected to replace, tests on a plant scale. This is due primarily to the fact that it is not yet possible to precisely reproduce plant conditions in the laboratory. Conditions of mixing are particularly hard to duplicate; and the degree of turbulence prevailing during sedimentation and in the transfer of the liquid from the flocculation to the sedimentation step are also difficult to translate from plant to laboratory terms. These statements are not intended to underrate the importance of laboratory tests; properly performed and interpreted, they can be a most valuable guide to the plant conditions which will produce the best results. However, having determined the conditions which produce best results in the laboratory, it is often profitable to experiment in the plant with slight deviations from those conditions to ascertain whether such changes may improve the results.

In plant-scale experimentation, it is not ordinarily possible to draw valid conclusions from a test of one or two days' duration unless the results are extremely poor. It is usually necessary to continue with a given set of conditions for at least a week, and preferably longer, to eliminate the effects of day-to-day variations and permit a meaningful comparison with another test period under different conditions.

Summary

An effort has been made to outline in a qualitative way the status of existing knowledge of the theoretical aspects of chemical coagulation and to show both the applications and the limitations of this knowledge. Probably this discussion has once again made apparent the commonly known fact that there is still as much art as science in

the chemical treatment of sewage. It is hoped, however, that a consideration of such basic knowledge as is available on the subject may prove of value to an improved understanding of the art.

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LIQUID NITROGEN USED TO FREEZE PIPE

By Willis M. Sparrow

Superintendent, Sewage Treatment Plant, Renton, Wash.

An unusual pipe-freezing operation recently solved an emergency problem at the Renton, Wash., sewage treatment plant.

The problem arose when a control valve in the plant building had to be removed for an overhaul. To control the flow from the digester, it became necessary to cut out a section of the line and install a gate valve.

This operation could be accomplished either by freezing the pipe and its contents or emptying the 500,000-gal digester. The latter would have required a complete shutdown of the plant.

Plant personnel first tried to freeze the pipe and its contents with 700 lb of dry ice. This attempt was unsuccessful and the Linde Company, Division of Union Carbide Corporation, was asked for suggestions.

Their engineer recommended freezing a section of the pipe with liquid nitrogen which has a temperature of $-320°F$.

A steel jacket to hold the nitrogen was designed by the company and fabricated at the treatment plant maintenance shop. The jacket was clamped around the pipe and injected with liquid nitrogen for 4½ hr, freezing the enclosed section and its contents. See Figure 1.

Water department employees then cut out a 2-ft portion of the pipe downstream from the frozen section with a power hack saw and installed the new valve. The entire operation required

FIGURE 1.—Steel jacket used to contain the liquid nitrogen.

less than 5½ hr and saved the city of Renton an estimated $2,000.

Officials of the Renton Water Department witnessed completion of the job and plan to use liquid nitrogen in a similar manner to repair water mains and branch lines. At present, water users on the line must be notified individually, and the entire line shut down to make such repairs.

TIPS AND QUIPS

Flight to the Suburbs

Burgeoning suburbs are causing some of the most difficult problems ever encountered in sewage collection and treatment. Even the most optimistic sewage works official must at times get a feeling of helplessness. Fortunately, this feeling lasts only a moment and we are more likely

to find him solving the new problems that seem to show up daily.

Nationwide statistics on metropolitan-area growth are sober reading but sometimes local statistics serve to increase our appreciation of this problem. As a case in point there are listed below some data from the last annual report of Fairfax County, Va., just across the Potomac from Washington, D. C.

Population:	
1930	25,264
1940	40,929
1950	98,557
1957 (est.)	203,000
Assessed value of real and personal property:	
1951	$168,545,507
1958 (est.)	416,281,500
Bonded debt (June 30, 1958):	
Hospital	$500,000
Court house addition	740,000
Health center	48,000
Schools	32,399,570
Sewer program	20,000,000
Total	$53,687,570
Sewage works:	
Population served by sewers	117,850
Sewer mains installed * (miles)	61
Sewers maintained by County (miles)	558
Pumping stations operated	21
Treatment plants operated	6

By-product Utilization †

Sulfite mills in Oregon and Washington are building a growing business in use of spent sulfite liquor as a road binder. Lignin—which holds fibers together—works well in holding unpaved road surfaces together, too. Last year spent sulfite liquor was applied to 4,669 miles of roads in the two states. Worked into surfaces, the liquor forms a long-wearing crust. Sprayed on, it holds down dust. Concentrated liquor has been exported to other states for experimental use. This by-product use by city and county road departments, private contractors, and other users is growing.

* During fiscal year 1958.

† *Northwest Pulp and Paper News*, **1**, 3 (1958).

Scum Breaker Upper

From Plainville, Conn., comes a tip by T. E. Fanion that ought to help operators who are faced with digester scum problems. Mr. Fanion, obviously a man with a tender back and a strong mind, simply got tired of fighting a one-inch fire hose nozzle hour after hour and did something about it. His homemade scum breaker upper is shown in Figure 1. Not only is scum-breaking made easier by using this tool, but it becomes a lot more efficient. To break up 4 ft of scum used to take from

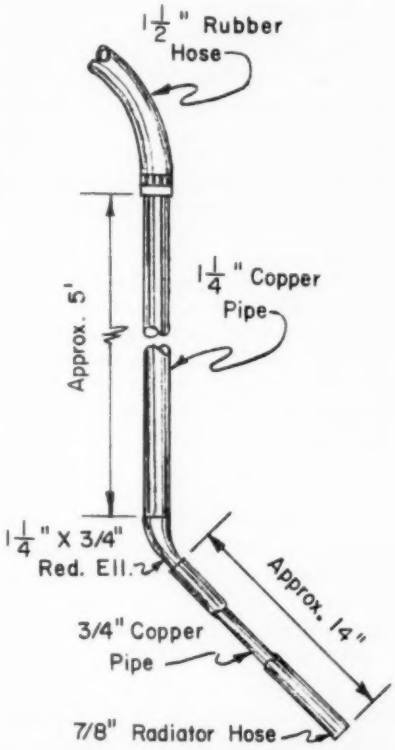


FIGURE 1.—Scum-breaking nozzle.

20 to 30 hr; now it can be done in half the time. With a water pressure of 65 psi, scum can be reached anywhere in the 35-ft digester.

The nozzle can be built as follows:

1. Take a length of 1¼-in. copper pipe and on one end sweat a nipple to which a flexible hose can be attached. The length of copper pipe used by Mr. Fanion was 5 ft but the length should be selected to suit your own digester. Generally, a length equal to the distance from your belt (when standing) to the bottom of the manhole will be comfortable.

2. To the lower end of the 1¼-in. copper pipe, sweat on a 1¼- by ¾-in. 45° reducing elbow.

3. To the reducing elbow sweat on a 14-in. length of ¾-in. copper pipe. To protect this short length of pipe, slip a piece of ⅞-in. radiator hose over it.

Heavy-duty copper pipe and fittings were used throughout because of their light weight and non-sparking quality. The tool shown in Figure 1 weighs about 8 lb. Fifteen feet of 1½-in. rubber hose was used to connect the nozzle to a 2½-in. fire hose. This made the nozzle easier to handle and cut down on on the weight.

When working on a digester in this fashion don't forget to have plenty of ventilation inside the tank. Remember that the removal of small manhole covers from the tank roof cannot be depended on to afford adequate ventilation under all conditions.

Sewer Safety Rules

The following safety rules for the interceptor crew were developed through the cooperation of the accident prevention committee and put into effect in Cincinnati, Ohio.

1. Adequate barricades and traffic diversion patterns must be erected around the work area before opening chamber.

2. Test for explosive mixture before and after removing manhole cover.

3. Test for lack of oxygen before entering chamber or conduit.

4. Hard-hats must be worn at all times.

5. Safety harness and line must be worn at all times when working below ground level.

6. When a man is working in a manhole or chamber where a safety harness is mandatory, adequate provisions for bringing him above ground without the aid of his own power must be established.

7. Smoking in any sewer conduit, chamber, or regulator is strictly prohibited.

8. Horseplay is strictly prohibited.

9. These rules apply to all persons working with or observing this crew, and violators are subject to disciplinary action.

Hand Embosser

You can make your own plastic and metal labels whenever you need them with a hand-size strip embosser (Figure 2). The "Midgie" embosser is

FIGURE 2.—Embossing machine.

manufactured by the Roovers-Lotsch Corp., 3611 14th Ave., Brooklyn 18, N. Y., and sells for $47. Labeling material is available in ½-in. rolls of monel, stainless steel, aluminum, copper, lead, and vinyl plastic. The plastic strips, with or without an adhesive backing, come in five colors. Adhesive-backed plastic costs about 9¢ a foot.

Editorial

DAZZLING DALLAS

Dazzling Dallas will be the setting for the 1959 Annual Meeting of the Federation. Being the only meeting with extensive exhibits in the wastewater technology field, it may be aptly termed the "greatest show on earth" to this field.

The essential ingredients of a successful annual meeting are many and varied. These include a good technical program with a broad scope and with an appeal to all who deal in sewage and industrial wastes as well as the general subject of water pollution. The program makeup must range from formal papers to informal discussions so that everyone can make his choice of both receiving information and participating in these discussions.

Another ingredient is the manufacturers' exhibits which for the Federation Meeting are operated by the Water and Sewage Works Manufacturers Association. Since the meeting is in the Dallas Memorial Auditorium, there will be ample room for the display booths which are expected to reach 100 this year. The crowding which has been an annoyance in meetings of recent years, will be entirely absent so that those attending the convention may benefit the most from the manufacturers' display offerings.

The Local Arrangements Committee, under the leadership of Henry Graeser of Dallas, has been occupied for many months in the painstaking details of providing the best support for the excellent meeting facilities and a social and entertainment program second to none. Special arrangements are being included for the ladies who will be attending the meeting and they are promised a schedule that will show them Dallas as well as give them some time of their own in Dallas' points of personal interest, including the great Texas State Fair. Inspection trips will give physical demonstration of how local wastewater is handled and treated.

While all of these ingredients are essential to a productive meeting, the priceless ingredient is the attendance and participation of the great number of individuals interested in sharing and exchanging information about their work. While most of these are Federation members, attendance at the meeting is not limited to members as all are welcome to come and participate. Make your definite plans now and when you receive the advance convention announcement with the hotel reservation card, send it in immediately to be assured of the accommodations you desire for the meeting.

The spice of the meeting may be considered the social program established for convention registrants. While the Federation Luncheon on Tuesday and the Industrial Wastes Luncheon on Wednesday will include outstanding speakers, the Wednesday Banquet will provide the setting for annual Federation award presentations. This event, with the dance following, is the highlight of the week's social events. An event truly Texas in magnitude and style will be the Monday night Chuck Wagon Dinner with appropriate entertainment. This event is beyond that normally provided by the Federation program and a material contribution to its cost is being borne by the Host Association.

Again, mark your calendar now! Whether D stands for Dazzling or Dallas to you, don't miss this full combination of Federation D Week in Dallas, October 12–15!

R. E. F.

Reviews and Abstracts*

The Effect of Temperature on the Aeration of Flowing Water. By G. A. Truesdale and K. A. Vandyke. *Water and Waste Treat. Jour. (Brit.)*, 7, 1, 9 (1958).

The effect of temperature (range of 8 to 40°C) on the rate of solution of oxygen was determined experimentally in channels each section of which had a different exchange coefficient. The oxygen content of the water was reduced to 10 or 20 per cent of saturation by the addition of the required amount of sodium sulfite with cobalt chloride as catalyst.

The exchange coefficient (f) when plotted against the temperature showed a linear relationship. The temperature coefficient, defined as the increase in exchange coefficient and expressed as a percentage of the value of f at 15°C per °C increase in temperature, varied from 0.81 to 1.84. The range of values obtained is greater than would have been expected from the accuracy of the determinations. The temperature coefficients did not vary in any regular way with the absolute magnitude of the exchange coefficient. The variations in temperature coefficient could not be attributed to any specific cause. It is concluded that the mean value of 1.5 per cent per °C be used for the temperature coefficient in flowing water.

H. Heukelekian

The Effect of Synthetic Detergents on the Rate of Aeration in Diffused Air Activated Sludge Plants. By A. L. Downing and L. J. Scragg. *Water and Waste Treat. Jour. (Brit.)*, 7, 3, 102 (1958).

The absorption coefficient and performance of a laboratory scale continuous flow diffused air activated sludge plant were studied in the presence and absence of detergents when oxygen supply was plentiful and also when it was deficient. Synthetic sewage was employed to which 10 ppm of anionic surface active agent was added.

With adequate oxygen supply, the absorption coefficient was lowered 34.5 per cent by the addition of detergent. This resulted in reduction of the average DO level from 5.2 to 3.3. mg/l. The performance of the plant including nitrification was not affected under these conditions.

With reduced air flow which did not permit complete nitrification, the addition of detergent depressed the absorption coefficient by 65 per cent. During the period when detergent was not added 60 per cent of the ammonia in sewage was converted to oxidized nitrogen. During the period when detergent was added, only 10 per cent of the ammonia was oxidized. The carbon content of the effluent also increased.

The performance of an oxygen-limited plant can be restored to its original value before the introduction of detergents by increasing the air flow to offset the reduction in the rate of oxygen absorption. When the absorption coefficient is reduced by 65 per cent, it is necessary to treble the air flow to achieve the required purifying capacity.

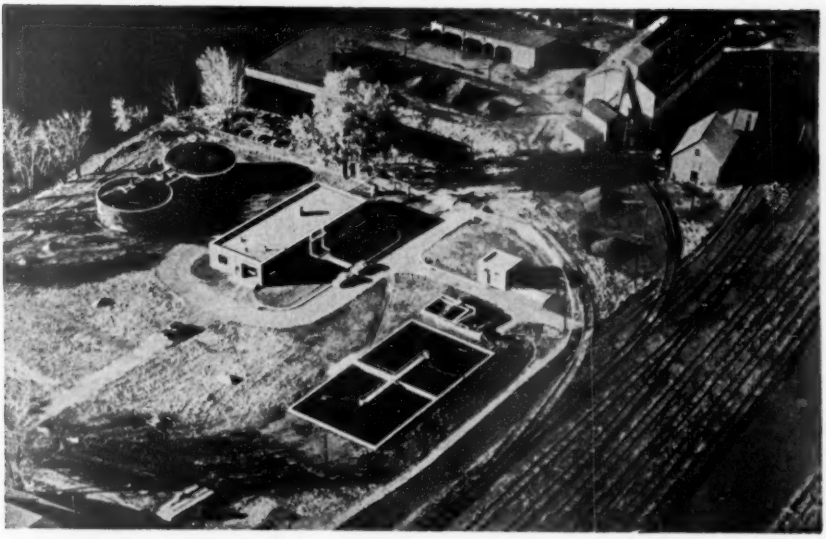
H. Heukelekian

Automatic Potentiometric Titration in Determination of Dissolved Oxygen. By V. S. Griffiths and M. I. Jackson. *Anal. Chem.*, 31, 161 (1959).

An automatic titration procedure is described where the electrodes monitor the reduction of manganic ions by ferrous ammonium sulfate in acid solution. The electrode pair consists of a lithium glass electrode and platinum.

R. S. Ingols

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N.W., Washington 16, D. C.



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VAREC SEWAGE EQUIPMENT

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S-13

Proceedings of Member Associations

FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 9th Joint Conference of the Florida Section of the American Water Works Association and the Florida Sewage and Industrial Wastes Association was held at the Golden Gate Hotel, Miami Beach, Fla., on Oct. 19–22, 1958. Nearly 450 members and guests were in attendance.

During the two-day technical session 13 subjects were discussed. These included: water supply and water pollution control research, operator certification and training, sampling programs for water and sewage treatment plants, developments in concrete pipe, use of radioisotope in sewage research, nuclear wastes, synthetic fabric manufacturing wastes, paper mill wastes, and combined wastes.

Federation Secretary Ralph E. Fuhrman extended the greetings of the Federation Headquarters Office at the Banquet and presented the Hatfield Award for outstanding treatment plant operation and reporting to Daniel J. Raye, Superintendent of Sewage Treatment, Clearwater. The Bedell Award for extraordinary personal service to the Association went to Ralph Baker, Sanitary Engineer, Florida State Board of Health, Jacksonville.

Officers elected for the year 1959 were:

(Continued on page 294a)

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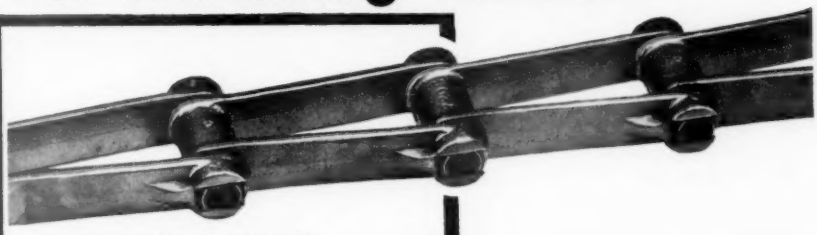

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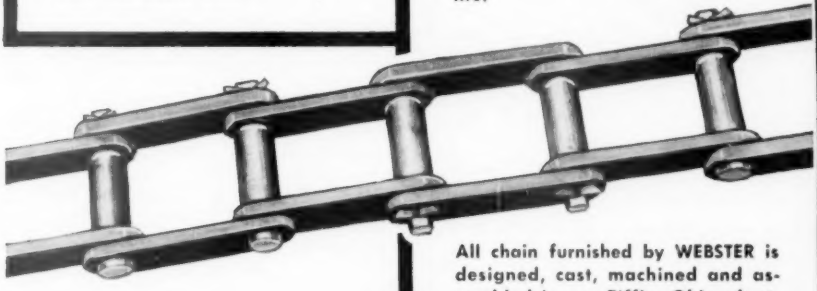

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ARKANSAS WATER AND SEWAGE CONFERENCE

The 28th Annual Meeting of the Arkansas Water and Sewage Conference was held at the Robinson Memorial Auditorium, Little Rock, Ark., Mar. 16–18, 1959. An attendance record was set when 307 registered.

The technical program was well balanced and well attended. Among the papers of particular interest to sewage and industrial wastes personnel were:

"Financing Water and Sewage Construction," by Henry G. Creel, Jr., Regional Director, Community Facilities Division, Housing and Home Finance Agency, Fort Worth, Tex.

"Screening of Sewage and Industrial Wastes," by Hunter McKay, Sales Engineer, Link-Belt Co., Shreveport, La.

"Sewage Plant Operations of Jonesboro, Ark.," by Neal Thayer, Manager, Water and Light Plant, Jonesboro, Ark.

"Construction and Maintenance of Sewer Lift Stations," by Donald N. Dodd, Engineer Consultant, Burns and McDonnell, Kansas City, Mo.

"Sewer Main Cleaning," by Porter Pryor, Sales Engineer, Delta Tool Co., Little Rock, Ark.

"Financing Water and Sewer Improvements," by V. J. Giss, Vice-President, Stephens, Inc., Little Rock, Ark.

At the Sewage Works Section's

(*Continued on page 296a*)

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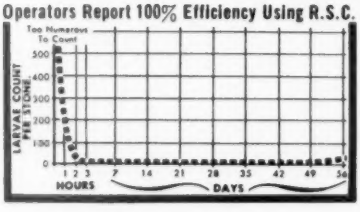

Test report 107-B
The Southwest Utilities Corp. in Houston, Texas, started the R.S.C. tests for Psychoda control on Sept. 9, 1958. Before treatment, Psychoda larvae under stones were too numerous to count. The premises were very heavily infested with adult Psychodae. Within 2 hours after treatment, no living larvae could be found in the bed. All adults on the premises were killed on contact with R.S.C. spray. Daily checks were made for Larvae to a depth of two feet below the surface of the filter stones. Larvae did not reappear until Oct. 27, 1958. Adult Psychodae did not reappear until October 31, 1958.

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luncheon, Federation President W. D. Hatfield presented the Hatfield Award for outstanding treatment works operation to Dan Millender, Superintendent, Water and Light Plant, Jonesboro, Ark. The Bedell Award for extraordinary service to the Conference went to Prof. C. W. Oxford, College of Engineering, University of Arkansas, Fayetteville, Ark.

New officers elected to serve during the year 1959–60 were:

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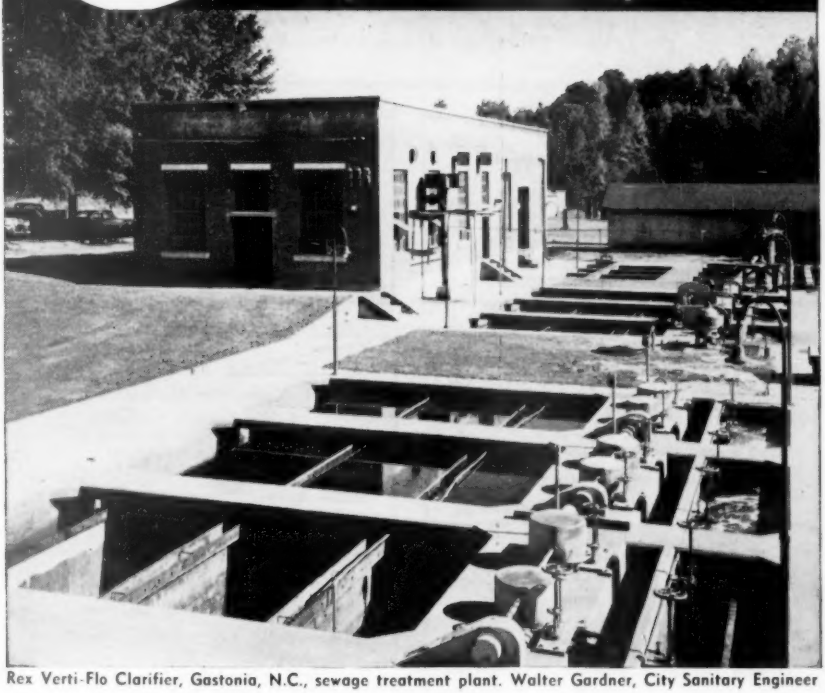

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(Continued through page 305a)

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